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Management of Combined Municipal Utilities

By Otto E. Eckert

IF WE can accept as a premise that the purpose of management of public utilities is the furnishing of a superior service at the lowest long range rates, we can make quite a case for combining the management of municipal utilities.

When the customer is applying for service he would obviously prefer to make only one telephone call or a trip to only one office to make his credit arrangements, and to give his "turn-on" order. The same thing applies if he wants to give a "turn-off" order.

When the customer has trouble to report, especially after office hours, one telephone operator takes the calls and passes them on to the proper service man who takes care of the trouble if it is of an emergency nature that calls for immediate attention.

When the customer pays his bills he can do so with one check or with one trip to the office. If he is financially embarrassed he makes his arrangements for the combined services.

If the prospective customer is planning to build in new territory he finds out about the possibilities for utility service at one place.

When streets or pavements must be excavated, one department is responsible and it is easier to assure quick completion of the work and proper safeguarding.

A paper presented on April 25, 1940, at the Kansas City Convention by Otto E. Eckert, General Manager, Board of Water and Electric Light Commissioners, Lansing, Mich.

There may be opportunities to tie plants together so that standby equipment for one utility may act as standby for others. For instance, in Lansing there are 10,000 feet of high pressure steam lines which tie three boiler plants together. Steam is used for pumping water, for generating electricity and for central heating. When the load is light, in late spring and early fall, the water plant boilers carry the central-heating load. In colder months, electricity is generated with non-condensing turbines from the steam-heating boilers, and the exhaust steam is used for central heating. Should it be necessary to shut down the steam-heating boiler, the heating load could be carried on boilers 8,000 feet away at the electric-generating plant. Few plants have taken full advantage of the possibilities of transmitting steam at high pressures. At Lansing, last year, over $200,000 worth of high pressure steam was sold to one large industrial customer. The customer profited because he did not have to invest in an expensive new steam plant to replace boilers that were worn out and inadequate; and the department profited in putting to work boilers that would otherwise have been idle.

Savings in Personnel and Finances

Better trained engineers and more skilled workmen are available for special jobs and emergencies. Being a combined utility, the Lansing department has been able to employ high grade personnel and pay them well enough so that the employee turnover is very low.

The combined finances and personnel are available to all utilities under one management. Less working capital is necessary, because emergencies are not liable to occur in all departments at one time.

Replacement and improvement programs can be scheduled so that the financial program is not burdensome. Lansing has been in the water business for 55 years, in the electric business for 48 years, and in the steam-heating business for 21 years. Money had to be borrowed on bonds to start each of these businesses. At only one other period, 1916 to 1924, when there was an unprecedented growth and cut-throat competition, did money have to be borrowed. No bonds have been issued since 1924, and the department has enough Government and City of Lansing bonds and cash on hand to pay up all outstanding bonds. They would be paid up now, but they are not callable and the owners will not sell them even at a high premium.

Extensions have been made and bonds have been paid up out of earnings; and taxpayers have not been called upon to pay for either.

In fact, in the last eight years the taxpayers have not been called upon to pay for public lighting or public water supply, both of which the department furnishes in lieu of paying taxes.

Every two years there is prepared an exhaustive study and report on the adequacies of the facilities, based on past records. Requirements for the next ten years are estimated and major capital expenditures are scheduled tentatively. In the last twenty years the department has bought out a competitive electric system; built two steam electric-power plants, four electric substations, a water-conditioning plant, a warehouse and shop, an office building, a dam; and has brought the distribution systems up to a very high standard.

Organization

The scheme of organization is as follows: There is a board of eight citizens appointed by the mayor for a term of four years. Two board members come up for appointment each year. This board, according to the city charter, has "full, complete and entire charge of the management, maintenance, repair, and control of planning, constructing, operating, maintaining and repairing all works of every kind already built and hereafter to be built, and used for the purpose of supplying the city and the inhabitants thereof with water, heat, electric lighting and electric power; said board shall purchase all materials and supplies therefor, including the right of way for water pipes, electric light poles, grounds for location for all necessary buildings, including wells to supply water, and make all contracts pertaining thereto. The conveyance of such right of way and the title of all grounds so purchased or otherwise secured, shall be taken in the name of the City of Lansing; and said water and electric light works, and everything pertaining thereto, shall be the property of the city, and all contracts and purchases made by said board shall be in the name of the City of Lansing."

The board members receive no pay for their services, nor may they be interested in any contract with the city.

The city charter also provides that "All the moneys raised by loan or otherwise for the construction, operation, management, maintenance and repair of any and all works, for supplying the city, and the inhabitants thereof, with water, heat, electric lighting, and electric power, as well as the purchase of supplies, materials, right of way, and grounds therefor, together with all sums to be collected for water, heating, electric lighting and electric power, shall be deposited

with the city treasurer and credited by him to the water-works and electric lighting funds, respectively, and shall remain to meet the liabilities incurred by the board, and shall not be withdrawn or used for any other purpose whatsoever."

The board has "full power and authority to fix all rates."

The board appoints two officers: a secretary who keeps "a complete account of receipts and expenditures," and who has charge of accounting and compiles a monthly budget for all departments; and a superintendent who has complete charge of the management of the utilities and who is responsible to the board.

Personnel

The principal department heads reporting directly to the superintendent are: Chief of Plants; Superintendent of Electrical Distribution; Superintendent of Water and Steam Distribution; Mechanical Engineer; Electrical Engineer; Purchasing Agent; Storekeeper; Office Manager; and Merchandise Manager.

The chief of plants has all stations and all production equipment under his supervision. Each station has a chief engineer reporting to the chief of plants. Working with the chief of plants, there is a building and grounds maintenance supervisor who has a nucleus of building trade employees, such as masons, carpenters, painters, handy men and laborers. Both equipment and building maintenance men are moved to various locations as they are needed.

The two superintendents of distribution have the duties that their titles imply. The superintendent of water and steam, however, takes care of all conduit and manhole construction work for the electrical distribution department, thus placing the responsibility for all work that may blockade streets or calls for street repairs, with one person.

The mechanical engineer designs and supervises mechanical changes in the plants and acts as the head of a test department that continuously checks the economy of operation of the production plants. This is done daily, actual results being compared with a "bogey" that it should be possible to attain. Detailed monthly operating results are compared with results of the previous month and with results in the same month a year ago, so that items that may be tending to increase costs can be quickly checked. Chemical laboratory work is under his supervision. The mechanical engineering department prepares the report on the adequacies of the facilities previously mentioned.

The electrical engineer designs and supervises the changes that must be made continually in the electrical distribution system to meet a growing load and to make use of more reliable electrical equipment that is continually being made available. Changes in electrical distribution have been much more extensive than they have in water distribution, principally because electrical distribution has been beset with more hazards, and because interruptions to service have been more frequent. The electrical engineer also supervises the maintenance of electrical equipment and protective devices that are beyond the routine of the plant operators.

The purchasing agent buys for all departments.

The storekeeper has charge of the warehouse, yard, garage and shops that serve all departments. All requisitions for materials pass through his department, and he accounts for the receipt and disbursement of all materials and supplies.

The organization outlined above has a large degree of flexibility and can be contracted in times of reduced activity and rapidly expanded if a large construction program is under way. Use is made of the services of consulting engineers, architects, and contractors on major jobs and the department is in a position to supply them with needed local information, and to understand and evaluate their recommendations.

The office manager is in charge of customer accounts, collections, and customer contacts for all departments.

A merchandising manager on the first floor of the office building sees to it that the department cooperates with merchants in the sale of electrical appliances, which it also sells. The department however, is more interested in selling the use of more electricity as a step toward reduced rates than it is in the sale of any merchandise for profit.

Customer Relations

A few things, that seem to be very much appreciated, are done for the customers:

For the water customer: Meters are checked in his presence if he requests it. If he complains about the quality of the water, or about deteriorating plumbing, he is called upon at his house, the trouble is investigated and explained, and, if possible, help in remedying the trouble is given him.

If a customer has an extra large bill due to a leak and makes

repairs quickly after he knows that the leak exists, the department splits the extra cost of his wasted water with him.

Water service from the main to the meter inside the house is installed at cost, and the service is guaranteed against future repairs.

New water mains are installed only where at least one house to every 100 ft. of main can be served, and only on streets where sewers are installed and grades established. This is at the expense of the water department. In case of a real estate development, the owners are required to advance the money for the installation of water mains, and that cost is refunded when the number of houses being served equals the requirements for minimum service. Because of these rules, there is very little idle investment in mains.

Pumping and distribution facilities are kept ahead of requirements, so there is no restriction of the use of water at times when the customer wants most to use it.

For residential electric customers: Free lamp renewals are furnished, with permission to take in exchange either a larger or a smaller lamp. Very few take the smaller lamp. Worn cords are repaired or replaced free of charge. Blown fuses are replaced with no charge for the call. Sixty-ampere entrance switches are furnished on new houses, so there will be no inadequate electric service. The reasonable cost of rewiring for electric ranges and water heaters is paid by the department.

For steam heat customers: The department studies the particular installation and operating conditions and advises the owners on how to save on heating costs if that is possible. Steam heating is available from September to June, inclusive, even though the amount of steam used in September and June is very small.

Results Shown

These have been the important items that, in the author's estimation, have contributed to whatever success may have been achieved by the department. The Lansing utilities are completely owned by the city. They represent a fixed capital investment of over $200 per capita. This has been acquired on rates well below the average in the state. The city has good schools, is well paved and well lighted, and on almost any basis of comparison would be rated among the best in the state. There is no school debt, no county debt, and only $10.32 per capita city debt. Tax rates have been among the

lowest in the state when compared with cities of over 50,000 population.

Based on his experience in Lansing and his knowledge of the experience of most cities that have the city manager form of control (Lansing has a council of aldermen), the author believes that cities, where they have not already done so, might well consider combining their city-owned utilities under one management. To do this successfully the utilities must be free from political control, they must have continuity of management, they must be required to operate and grow on their own income and must not be required to finance other city departments. They must pay wages that will attract and hold a high type of employee. These things can be done under any form of city government.

Discussion by *F. W. Martin.* * Mr. Eckert has pointed out the efficiencies to be gained by combining municipal utilities. The writer, during the past twenty years has been engaged in the management of both private and municipal enterprises, and in his experience has become aware of many interesting factors relating to this same subject of efficient management. There is no fundamental economic or engineering reason why a municipally owned utility should not be operated just as efficiently as a privately owned one. In the majority of cases, however, the municipal utility suffers in the comparison.

There are several reasons for this condition, the first and chief lying in the attitude of the citizens of the community. Do they really want efficient management of their utility properties or are the different factions more interested in carrying out their own pet ideas than in the permanent welfare of the utilities? To operate successfully, a municipally owned utility must be kept free of politics. This applies to personnel, purchasing of supplies, billing of services and handling of funds.

The ultimate downfall of a large percentage of municipally owned utilities has been caused by the failure to set aside adequate depreciation and expansion reserves in sound negotiable securities until the money is needed by the utility property. Depreciation charges are just as much an expense of operation as direct labor or consumable

* Superintendent of Utilities, Hinsdale, Ill.

supplies. Failure to provide a sufficient depreciation reserve will one day find the utility with old, worn out, broken-down equipment and with no money to replace it. Failure to set aside adequate expansion reserves will bring the utility face to face with a heavy load and no equipment to handle it, and, worse still, no money with which to purchase such equipment.

A utility to be operated economically and successfully must have a staff of properly trained men. Such a staff cannot be organized if political allegiance is the chief requisite for a job. It requires time to train a staff of men and if the personnel is to be changed every three or four years with the political party in power, there is neither time nor incentive to carry on this educational work.

As Mr. Eckert indicated, the operation of a group of utility services, such as electricity, water and heat, under one head leads to many worthwhile economies, particularly for the smaller community. It can hire a much higher grade of man to operate the group than it could afford to employ for any of the utilities singly. The meter reading, billing, collecting and bookkeeping for the entire group can be done in one office and by one staff. Much of the operating and maintenance labor can be performed by the same men.

Combination at Hinsdale

The Village of Hinsdale, Illinois, owns and operates its own electricity plant, water softening and pumping plant and artificial ice plant. The supervision of these utilities is vested in a superintendent of utilities appointed by the president of the village with the consent of the board of trustees. The superintendent reports directly to the board of trustees. In order to facilitate their work the president appoints a committee of three members of the board to watch over the details of the superintendent's work.

The utilities, exclusive of the meter reading and billing are operated by a staff of 21 men. Young untrained men with substantially a 4-year high school education are employed in the lowest positions. These men are required to supplement their work with correspondence school courses. If both their work and study are satisfactory they can expect annual salary increases for four years. They are eligible for promotion to the next higher position, with consequent salary increases, when a vacancy occurs. In this way trained men are always available for the higher positions. The system encourages

the men to put forth their best efforts, making for a high morale and consequent high operating efficiency in the organization.

The electric plant is operated by three watch engineers and three firemen working three shifts. A relief engineer and a relief fireman spend one-half of their time operating the plant on the days the regular men are off and the other half on maintenance of the electric plant, water plant or ice plant.

The maintenance foreman and his crew are responsible for the upkeep of all three plants.

One operator handles the pumping and softening of the water, working one shift of eight hours a day. Twice a week he is assisted by a janitor. On the operator's day off and during the summer months when the pumping is too heavy to be taken care of in one shift, as well as when the operator is away on vacation, the water plant is operated by a free lance man who acts as assistant to the superintendent. This man is capable of handling almost any job in either the electric, water or ice plants. The watch engineer on duty in the power plant takes care of the ice plant compressors and the water plant pumps during the evening and night shifts.

One man operates the ice plant during the summer months. The balance of the year he works in the maintenance crew.

These plants are all situated close together so one man can look after all of them during the night shifts. In this way a minimum of labor is required.

A line crew, consisting of a foreman and two assistants, takes care of the maintenance and operation of the electric distribution lines. In the summer, a fourth man is added to the staff.

Metering and Billing

Two men are employed in the meter department. These men install, remove, test and repair all electric and water meters. They also investigate all customer complaints and replace broken or burned out street lights. One of the men holds a federal radio operator's license and takes care of the two-way police radio as well as inspecting all electrical work done in the village to make sure that it complies with the electrical code.

All electric and water services are metered.

There are between 2,500 and 2,600 electric meters and between 2,000 to 2,100 water meters in the village. One meter reader working

out of the collector's office reads all electric meters each month and all water meters every three months. He subtracts the readings in the meter book and these are later checked by the billing clerks. During the last few days of the month, the meter reader operates the addressograph.

All bookkeeping, billing and collecting, as well as the payment of all bills, is taken care of by the village office staff under the direction of the village collector. A portion of the office expense, including salaries and rent for office space, is allocated to the utilities. This is divided between the electric department and the water department.

Separate accounts are kept for each of the utility departments. The salaries of those men working in more than one department are divided proportionally between the departments. Inter-department service is charged for at approximately direct cost.

The village clerk also acts as village purchasing agent. All purchases of supplies or repair parts are made by him on the request of the superintendent. For standard materials, the purchasing agent takes quotations from the various manufacturers and purchases from the lowest bidder. Special articles are purchased on the recommendation of the superintendent. Yearly contracts are made with the suppliers of such materials as lime, soda ash and sodium aluminate used by the water softening plant. Boiler tests are run with various coals and that coal is purchased which the tests indicate will give the village the lowest cost per thousand pounds of steam at the price quoted.

Prices and quality of goods and services being equal, preference is given to local dealers, but, as one board member put it, "Not one damn cent bonus."

Finances

At the beginning of each fiscal year a budget is set up for each utility. This includes operating and new construction expenses. It is based on the estimated income for the year. The income estimate is always on the conservative side.

Each month, the collector furnishes the superintendent and members of the board with a statement showing the income for the month and the cost of operating to that date as well as the balance left in the budget. The superintendent gives each board member a monthly report showing the operating results for the month compared with

the same month of the previous year. In this way the expenses are kept strictly within the budget amounts.

Depreciation is charged at an average of approximately 4½ per cent on the electric plant and 3½ per cent on the water plant. These funds are invested in negotiable securities, mostly government bonds, or in necessary plant expansion.

There is no favoritism shown in the collection of electric or water bills. The rule is, "No money, no service." The efficacy of the attitude is reflected in the small amount of uncollected accounts. On March 1, these amounted to a total of $700 for the electric plant, with average monthly collections of $14,000, and $500 for the water plant, with average quarterly collections of $14,000.

The operation of the utilities is kept separate from the general village affairs and a net profit is turned over to the general village fund for municipal operations. This is in lieu of taxes and a dividend on the investment in the property. No attempt is made to earn a profit on the water plant, but, in order to be safe and not go on the red side of the ledger, a small profit is earned.

A Customer Service Bureau

By Hal F. Smith

THE Detroit Department of Water Supply has always been interested in the subject of customer relations. Recently it welcomed the opportunity to take part in a series of meetings on this subject, sponsored by the Detroit Bureau of Governmental Research and the School of Public Affairs of Wayne University. These meetings were attended by representatives of the several municipal departments of Detroit and representatives of industrial establishments, including the local privately owned public utilities. The meetings afforded an opportunity for the department to check its ideas and experiences with those of private industry, a governmental research body, and the department of Wayne University which specializes in public affairs. It appeared, in fact, that all groups profited by the meetings.

The members of the water department became more than ever convinced that municipal water utilities cannot expect to compete with private business for customer good-will simply by furnishing its customers an ample and constant supply of pure and wholesome water at low cost. Water consumers in Detroit have been getting these things for so long that they take them for granted. Consequently, what degree of customer good-will the department enjoys or can gain is dependent largely upon its personal relations with its customers, or in other words, upon the brand of customer service it renders.

At the time it was necessary to make a self-inventory to determine just what, if anything, was wrong with the customer service. A casual observation indicated several deficiencies. As the subject was further investigated, it became apparent that a comprehensive

A paper presented on April 23, 1940, at the Kansas City Convention by Hal F. Smith, Senior Administrative Assistant, Department of Water Supply, Detroit.

survey was needed to get to the bottom of the question. It was felt that it would be almost impossible to have an impartial survey made by any regular employee of the department, if for no other reason than that he would have been so close to the picture for so long that it would be difficult for him to differentiate between right and wrong, as measured by the new standards which had been developed in the series of meetings on customer relations. The department was fortunate in being able to secure, for this survey, a graduate student of Wayne University who had specialized in public relations and who had had some practical public utility experience.

Survey Method

The survey was conducted along the lines prescribed by the management of the department and in cooperation with the heads of the various bureaus of the commercial division. In fact, the entire staff of the commercial division cooperated in the survey in an effort to find out just what was wrong and how it could be improved.

The survey included consideration of departmental rules and policies; personnel, both as to selection and training for customer contact work; office arrangement; the speed and thoroughness with which complaints were investigated and service orders executed; and, of course, the precise manner in which personal contacts, telephone contacts, and correspondence were handled by employees of the department. In order to determine the precise manner in which customer contacts were handled, a stenographic record was taken of 620 transactions. These records were taken at the various points of contact throughout the department and under varying conditions. At times the clerk knew that the conversations between him and the customer were being recorded, sometimes both he and the customer knew it was being recorded, and sometimes neither knew. Special telephone equipment made it easy to cut in on the call and record both sides of telephone conversations without either person's knowing about it, although there never was any intent to record the conversational part of a transaction without the clerk's knowledge. It is felt that the splendid cooperation given by the employees was due largely to the fact that they were, in this way, taken into complete confidence and given to understand that there would be no spying tactics used, and further, that the name of the clerk involved in the transaction would not be recorded, as the purpose of the survey was to discover how transactions were being handled in an effort to

determine how a better procedure could be evolved. After about four months' study of the operations and procedures listed above, the results of the survey were tabulated and classified.

Findings of Survey

Time does not permit a complete listing of the facts disclosed by the survey, but among them were the following:

1. Certain departmental rules and policies were causing a considerable amount of customer dissatisfaction.

2. There was a tendency to receive complaints as a criticism against the individual employee or against the department, rather than as an opportunity for the department to clear up a misunderstanding.

3. Many of the clerks, who were attempting to handle customer transactions, were not thoroughly informed on departmental rules, policies, and procedures.

4. There were frequent and unwarranted delays in completing investigations of complaints and in executing orders.

5. The general arrangement was bad, in that customer inquiries and complaints by person, telephone, and mail, were being referred to the various bureaus directly concerned. This arrangement is unsatisfactory because it is inconvenient for the customer and because it forces the customer to report his complaint directly to the bureau which presumably is responsible for the situation that caused the dissatisfaction. It is difficult, in such a case, for the responsible bureau to approach the customer with an open mind and to consider the question from the customer's viewpoint because of the natural urge to defend its own operations.

6. With customer contacts scattered so widely throughout the department, and because they were not being handled by any one definite group of employees, it was almost impossible to give the instruction and supervision necessary for satisfactory and uniform customer treatment.

7. Under this arrangement, responsibility of handling the complaint was often divided between several bureaus, an arrangement which is obviously unsatisfactory for all parties concerned.

8. A study of the recorded transactions indicated that they could be smoothed out and improved considerably by the use of planned transactions. Perhaps the term "planned transaction" needs some explanation. At the time that the survey was made, it was felt

that, since many transactions between employees and the public recur frequently in almost identical form, in all probability the majority of transactions could be classified into relatively few types. A study of the 620 representative transactions proved this to be true. Each type was then broken down into its various steps and analyzed. In other words, a "job analysis" was made for each type of transaction. Transactions were then developed or "planned," using the job analysis as a minimum standard of performance. The study has also disclosed that if the bulk of the employees' transactions are planned, the unusual cases, which occur so infrequently that they cannot be typed, will also be handled better because of the general habits and attitudes which have been developed by the use of planned transactions in other types of contacts.

Improvements Projected

With this information at hand, consideration was given to the proper corrective measures to be taken. It was evident that the first step should be the centralization of customer contacts. This is now being accomplished by the establishment of a customer service bureau which is made responsible for the handling of all customer inquiries, orders, and complaints, whether such are made in person, by telephone, or through correspondence. These activities, which formerly had been handled by the customer accounting bureau, the collection bureau, and the meter reading bureau, are being transferred to the customer service bureau, thus leaving each of the three bureaus mentioned to concentrate on the particular function for which it was organized, without the interruptions of customer contacts. The new bureau will be manned entirely by employees transferred from the other bureaus of the commercial division, although not necessarily by the same employees who were engaged in customer service work under the old system.

(When this paper was being prepared, the preliminary training was about half completed. The organization plans were complete, but the Customer Service Bureau was not to be put into operation until a little later. This will explain to the reader what otherwise might seem an unnecessary mixture of tenses.)

The bureau, as organized, consists of six sections, as follows: (1) service counter; (2) telephone and records; (3) correspondence; (4) stenographic and typing; (5) field representatives; and (6) control clerk. The service counter is located on the first

floor, adjacent to the tellers' cages. The combination desk and counter plan is used, wherein a number of clerks are regularly stationed at the counter and three at desks in a fenced-off space behind the counter. All customers who call in person are directed to the service counter where they are met by a clerk who is trained and authorized to handle the transaction in its entirety. All customer records are made available to the clerks at the service counter by means of special telephone service between the counter on the first floor and the central record room on the fourth floor. Short transactions are handled at the counter, while long or difficult ones are handled by clerks at the desks.

All incoming customer telephone calls are referred to the telephone and record section. This section is covered by special tele-

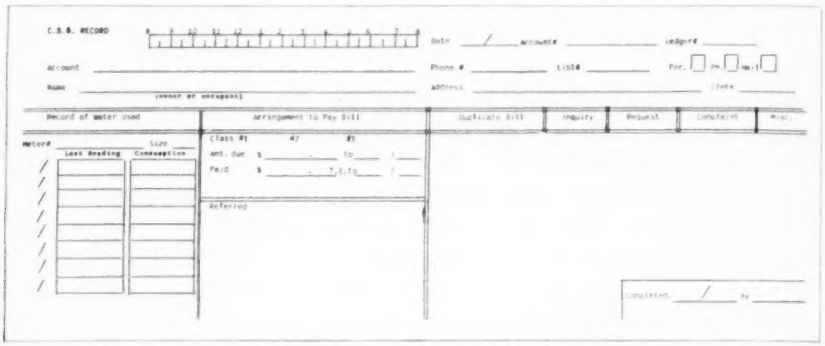

FIG. 1. All-Purpose Form, for use of Customer Service Bureau

phone equipment consisting of ten key cabinets, of eighteen lines each, ten lines coming from the phones at the service counter and eight from the main switchboard. The key cabinets are common to the ten extensions at the service counter and to the eight lines from the switchboard; therefore, when a clerk at the service counter removes the receiver of his instrument, it flashes a signal on each of the ten cabinets in the record room, so that the call may be taken by any one of the ten clerks who is not busy at the moment. Likewise, any incoming call referred to the record room by the switchboard operator flashes a signal on all ten cabinets, thus making it possible for the call to be taken by any clerk.

All correspondence is referred to the correspondent who is responsible for its final disposition, although contacts with other members of the staff are frequently required before the transaction can be completed or the correspondence answered.

Each customer contact, whether by person, telephone, or correspondence, is recorded on an all-purpose form (Fig. 1). This form is filled out by the clerk making the contact and passed on to the control clerk who makes out the required work orders and refers them to the proper department for execution. He also maintains a pending file for all work orders or investigations in progress. All the statistical data of the customer service bureau are obtained at this point by compiling and tabulating the data indicated on the all-purpose forms.

Personnel Training

The department is well aware that the success of the bureau depends almost entirely on its personnel. For this reason, a great deal of care was taken in the selection of a staff and in training the members for the work.

The second step was the installation of an employee training program.

From the beginning the conviction was held that satisfactory results could not be expected from a makeshift training program, but that a comprehensive, well-planned in-service employee training program would be required. Advantage was, therefore, taken of the provisions of the George-Deen Act. Under the provisions of this act, and with the cooperation of the State Board of Control for Vocational Education and Wayne University, the department was able to secure the services of the man who had assisted in the survey as a special instructor. This was financed under an arrangement whereby 75 per cent of the expense of the training program is reimbursable from federal and state funds. The instructor, with the assistance of several supervisors of the commercial division of the department, developed the training program. It was decided, at the outset, that the employee training would be done on company time and that the conference method of instruction would be used. The forty employees of the customer service bureau have been divided into four groups of ten each and a schedule for group meetings worked out so that each group will hold a two-hour conference every other day for a period of five weeks. Subjects for discussion for each meeting are assigned in advance, together with a specially prepared text on the subject. The employees are expected to study the text prior to the group meeting so that the two-hour conference period can be devoted entirely to discussion of the subject and explanation of points that have not been understood.

Scope of Program

The following outline indicates the scope of the training program:

1. Introductory meeting where the purpose and scope of the training program are explained to employees of the customer service bureau.

2. A conducted tour through the Water Works Park pumping station and filtration plant and other properties of the department, such as the storage yards and the meter shop.

3. The showing of a five-reel voca-film on customer service.

4. A session on the history and general statistics of the department.

5. A session on organization and procedure.

6. Several sessions on departmental rules and regulations.

7. Several sessions on rates, procedures, and forms.

8. A conducted tour through the Springwells pumping station and treatment plant, and through the new sewage disposal plant.

9. A session on the correct use of the telephone including the showing of a specially prepared moving picture on the subject, together with actual practice on the so-called "voice mirror," an instrument furnished by the telephone company to assist in the teaching of voice control and telephone technique. One simply speaks into the instrument and holds a receiver to his ear and after a delay of a few seconds his own voice returns to him, thus giving him an opportunity to listen in on his own conversation. As may be expected, this experiment never fails to produce a great many surprises.

10. Group meetings on collection policies and routines, departmental policies, penalties and adjustments, and sewage disposal billing and collection procedures.

11. Several sessions on planned transactions to complete the preliminary part of the training program.

Upon completion of the conference sessions described above, it is expected that the employee will be ready to take over his duties in the customer service bureau, but he will be subject to "on-the-job" training for several months, during which period emphasis will be placed on the use of planned transactions and their practical application. During the latter part of the training period, conferences will be held, as required, to round out the course. Immediately following the five-week schedule of group meetings for the customer service bureau, a similar series of meetings for meter readers, de-

linquent bill collectors, and other groups whose duties bring them into contact with the public will be arranged.

This idea of in-service training for public employees is comparatively new in Detroit. The work along this line has created considerable local interest and one of the questions most frequently asked is, "What is the employee reaction to this program?" This question may be answered by explaining that, from the beginning, it was felt that the employees of the department would cooperate with the management in developing and carrying out the program, but the degree of enthusiasm manifested and the willingness of the employees to extend their efforts far beyond that which was originally expected is surprising, even to those who had complete confidence in the staff in the first place. It is felt that the employee response as demonstrated is one of the worth-while discoveries of the program. It certainly will tend to encourage further development of the in-service training idea for public employees and should tend to correct the erroneous, but widespread, impression among certain groups of private citizens, that public employees are a peculiar breed of individuals who are interested in nothing but their pay checks.

Special Rates and Free Water Service

By Dale L. Maffitt

DURING the last few years there has been a renewed tendency on the part of water users, both domestic and public, to request from public institutions and agencies special concessions and emergency measures that at one time would have received little consideration. One of the effects of this effort on local water departments has been an increasing demand for special rates, not only to strictly public groups, but also to private enterprises.

Most cities have some system of sliding scale rates which is applicable to all classes of consumers; the larger users, however, pay for their water at a lower rate than do smaller consumers. This has been carried so far in some communities that large consumers may obtain certain portions of their water at rates below actual cost of pumping and treatment.

In some cities green grass is now subsidized by means of special rates for lawn sprinkling. Sometimes, special rates are also charged for water used for air-conditioning. In addition to this, it is also necessary to establish a special rate, or ready-to-serve charge, for fire protection services, both public and private, unless, as is often the case, these services are free.

The granting or denying of special rates is greatly influenced by local conditions. For instance, there may be what might seem a large excess capacity at the water plant that could be utilized at a very low cost; or special rates may be the result of a political compromise wherein the results obtained seem to be worth the rate concession.

If a group of leading business men of a community call upon the city council or the board of water commissioners, asking a preferred

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A paper presented on April 23, 1940, at the Kansas City Convention by Dale L. Maffitt, General Manager, Des Moines Water Works, Des Moines, Iowa, to open the round table discussion on special rates and free water service.

rate to a large industry to induce them to build in the city or to keep the factory from shutting down or moving away, it might be hard to refuse the request, even though the rate were discriminatory as regards other consumers.

Ohio Law on Free Water

In the matter of special rates for industrial use of water, a very concise summary of the salient points of law in Ohio, regarding proper rates chargeable to large consumers, may be found in a paper by Philip Burgess (Jour. A. W. W. A. 29: 213 (1937)) consulting engineer of Columbus, Ohio, as follows:

"1. In computing the cost of industrial water, it is not proper to include the cost of services or equipment which do not benefit the consumer in question.

"2. In computing industrial rates the cost of service as a whole must be considered and not merely those costs commonly called 'out-of-pocket costs.'

"3. Expediency does not justify discrimination.

"4. A municipal water plant in Ohio cannot be operated at a profit and must conform to the same rules and regulations as those of a private utility with respect to the rates charged.

"5. A water rate schedule containing a sliding scale with a ratio of 1 to 9 is discriminatory and cannot be sustained or justified."

The law in Ohio may not be entirely applicable in all states but these five points seem to be a good guide to anyone making a special rate schedule.

Promotional Rates

The statement that "expediency does not justify discrimination" should be a first rule in the rate-making program. Yet there has seemed to be a growing practice of extending so-called "promotional rates," that is, special rates for such purposes as lawn sprinkling and air-conditioning. In the case of air-conditioning, where the water can readily be separately metered, the situation becomes the mere disposal of a surplus commodity at a reduced price, and it introduces the difficulties which usually accompany surplus commodity disposal.

Lawn-sprinkling rates have developed according to a more varied pattern. It is our understanding that in one southern city, a reduced rate was allowed for lawn-sprinkling water, using the previous sum-

mer consumption as a base for determining the amount of the total bill due to lawn use. Other cities have used the water consumption during the winter months as a basis of computation for lawn-sprinkling charges, and there has been wide variation in the amount of rate reduction allowed. In some cities the purpose of this form of special rate has been primarily a civic project to aid in beautifying the city, as in a western city, where the lawn-sprinkling rates are charged according to the number of front feet of property served.

With a few exceptions, lawn-sprinkling rates have not proved very successful economically, and have not greatly increased consumption. In some places, however, the better consumer relations established have been reported to be worth the added expense.

At the time a special rate is made, it is usually considered of mutual benefit to the recipient and, in one way or another, to the *city*. The city and the water department, however, are not always one and the same—and the water consumers and the taxpayers are not altogether one and the same. If one group of consumers or one individual receives more than he pays for, the burden must be borne by the others.

Free Water for Public Use

Probably few cities pay as much for their water used for public fire protection as this service costs the water department. Also, in the case of private fire sprinkler services, where the individual desires something more or better than is furnished by the public for his fire protection needs, the favorite argument for free service or for a very low rate to him has been that the community as a whole benefits by the more adequate protection of his property, because it lessens the likelihood of a fire starting on his premises and spreading to others. Probably very few persons installing automatic sprinkler systems are actually motivated by such altruistic purposes, but are likely, rather, to be more interested in lower insurance rates for themselves than in the welfare of their neighbors or the taxpayers as a whole.

The water works literature for years has contained abundant material regarding free water for public uses. The majority of opinion has long been that it is more equitable that all such water be paid for from tax-collected revenue. Nevertheless, the number of cities furnishing free water continues to grow, and more recently the percentage of the total water used by public agencies in cities has

increased, probably influenced by the advent of Works Progress Administration and Public Works Administration projects replacing private contractors on public work.

In a few smaller municipalities the water rate payers not only furnish free water to the town but the income from the municipal water plant, sometimes augmented by the income from the municipal power and light company, has been used to replace city tax levies completely.

One point about which there seems to be quite general agreement in regard to free water to public buildings, schools, swimming pools, golf courses, etc. has been the fact that it seems desirable that all such water be as carefully metered as though it were to be paid for. This not only tends to discourage wasteful use of water, but it gives all parties concerned a clearer knowledge of what this use of water amounts to and just where it goes.

Higher Rates to Suburban Consumers

Special rates are not always reduced rates. In a questionnaire answered by 77 of the larger cities of this country, it was shown that in approximately 75 per cent of the cities, higher rates are charged consumers living outside the city limits than are paid by those living in the city, and these rates sometimes run as high as 100 per cent greater.

There has been a rapidly growing tendency to add to the consumer's water bill an additional charge for the purpose of supporting the local sewage disposal plant. While these charges seem to be more reasonable than the time-worn practice of asking the water consumers to pay fire protection expenses, the net result is much the same, that is, placing a levy, that would otherwise be an additional general tax, on a selected group of taxpayers.

This paper is intended to call attention to some of the more common forms of special rates or free uses of water, together with experiences that have resulted where these rates have been used. In summary the following points should be emphasized:

1. Present large excess plant capacities or reserve supplies may be needed tomorrow.
2. Special rates once made are hard to rescind.
3. Revenue from water users should support the water department, but public uses of water should be paid for by the taxpayers.

4. There is no such thing as free water in the sense that a plant once established can increase its output at only nominal expense.

5. All free water should be metered.

6. Expediency does not justify discrimination.

The general public should be made to realize that the operation of a water plant is a definite and distinct business in that it is called upon to furnish an adequate supply of water both for domestic and public consumption whenever the water is needed. Large capital outlays in plant are necessary to insure the delivery of a potable and wholesome water for the entire community and a reserve, adequate at times of drought, of abnormally increased consumption, and of fires which might develop into a state of conflagration.

Experiences With a Department Newspaper

By George S. Bonn

NOTHING is more important to a community than its supply of pure drinking water. Producing and maintaining that supply is one of the community's most important enterprises; and because it is so important, the water departments in most cities are to be numbered among its largest organizations. They have capital investments of millions of dollars in plant, property, and equipment; they spend thousands of dollars every year to maintain and improve the water works system; they employ hundreds of people to do the maintaining and the improving; and, of course, they continually have problems to handle.

Every once in a while the grade schools and high schools of the country become interested in water supplies. Students write to the local water department, asking for information on its water supply system. Frequently these students ask specific questions; and whenever they do, one question almost invariably is "What are your most important water supply problems?" Just as invariably, back goes the answer "Our most important problem is to supply the city with pure drinking water."

But there are other problems, problems of management, that the school child wouldn't understand and, all too frequently, that the management itself does not fully appreciate. Because of the size of many water departments, a large management problem is that of getting all the employees to know each other and to know what is going on in the department; in other words, they must develop a *community spirit.* Combination departments, including two or more different utilities, are even larger and the business of developing a family or community spirit, and of letting the family know what is

A paper presented on April 25, 1940, at the Kansas City Convention by George S. Bonn, Research Engineer, City Water, Light & Power Department. Springfield, Ill.

going on, is just that much more of a problem. The water, light and power department in Springfield, Ill., is such a combination department, employing about 260 people.

News-Magazine an Aid to Employee Relations

One way that has been found to help solve this family and news problem is the publication of a news-magazine similar to the house organs of many of the large industries of the country. Railroads, manufacturing plants, department stores, private utilities, and even some cities have house organs. Some of them, with which we are all familiar, are the *Illinois Central Magazine*, *Baltimore and Ohio Magazine*, *Westinghouse Magazine*, *Ford News*, *Monsanto Current Events*, *Mueller Record*, *The Cooperator* of the H & S Pogue Company of Cincinnati, *Bressmergrams* of the John Bressmer Company of of Springfield, *Bell Telephone News* of the Illinois Bell Telephone Company, *CIPSCO News* of the Central Illinois Public Service Company, *Fort Wayne Municipal Review*, and *The Hall Light* of Baltimore. These organizations have learned the actual dollars-and-cents value of their own news sheets. If there were no good reason for putting out a house organ, it is not likely that any of these efficiently operated companies and municipalities would even consider the idea. As organizations, however, they have learned that before public good-will may be achieved, they must have employee good-will. There must be a community spirit within the company, an *esprit de corps* if you like, that makes every employee realize that he is a very real part of the firm, no matter how large it is, and not just a name on the payroll. Employees who know and who are aware of each other and each other's interests are more likely to try to know and try to be aware of their customers and the customers' interests. These organizations also have learned that it is a good thing to have the employees know what is going on around the plant, what new improvements are being made, what new products and processes have been perfected, who the important visitors have been, and, most certainly, what the operating problems of the company are. To know these things is to be armed, literally, to the teeth because employees are asked questions. An intelligent answer is, like virtue, its own reward and it frequently "turneth away wrath." The company news-magazine or house organ fills a most important need in building and maintaining a family feeling within the organization and in bringing before the employees its own important news.

The *Waterlite News*

The City Water, Light and Power Department in Springfield is learning the benefits of a department paper. Its news-magazine, a monthly bulletin called the *Waterlite News*, is published, as it proudly states on its editorial page, by and for the employees of the department. Its avowed purpose is, like its many industrial brothers, to give information and to entertain at the same time.

Employees in any large organization all too frequently are completely ignorant of the work done by the department outside their own small sphere. Telling these workers about the various jobs that must be done makes everyone feel more like a *member* of the of the organization rather than just an employee. Perhaps a new construction program is under way or perhaps the lake is being riprapped. Maybe the 15-million-gallon pump is being repaired or a new type of accounting machinery has been installed. An improvement may have been made in the method of adding chemicals to the water, thereby saving the department $1\frac{1}{2}$ cents per million gallons. Anything that the department does should be explained to every employee. A regularly issued paper can tell them in a way no other department publicity can.

Employees often wonder what a certain company does with so much water or power; and unfortunately no one answers. A department paper, however, can answer such questions very easily. Most industries are only too delighted to have both visitors and publicity; if they get both at once, they are even more pleased. An inspection trip through a factory or dairy or coal mine will give some member of the newspaper's staff all the information he needs to write a story on why and how that industry uses water or power.

Here, also, is an opportunity for the department paper to make itself more worth while, by promoting customer relations. The industry that finds that the local water department is taking an interest in it to the extent of touring the plant to write an article for the department paper will think more kindly of the department, and so will the industry's employees and friends. Then, too, the department will be able to learn more about the problems and processes of the industry, so that it will become more than just another account number.

The *Waterlite News* carried a series of articles on the large power and water users of Springfield. A reporter went down into the

deepest mine in the city to get material for a story which was called "Water, Light and Power 255 Feet Underground." Another story was "Light and Power in a Milk Plant"; and still another, "Water and Light at Hummer's," (the Hummer Manufacturing Company). Incidentally, excerpts from these stories appeared in one of the local newspapers, giving both the concerns and the department a little favorable publicity.

Advantages of Exchange Material

Exchanging papers with other departments, with other cities, with industries, with any organization, in fact, that publishes a house organ, is one of the most interesting benefits of a department news-magazine. First it is learned what other organizations are doing, what additions or improvements they are making, what new methods or processes they are employing, or perhaps that Miss Mamie Downspout, the superintendent's secretary, is going to be married. All of these items are interesting because similar events happen in the local department. Then, too, the sales campaigns that are being featured by other organizations and their effect on the public, and facts about other cities and other people are to be discovered. Toward these same ends the department news-magazine often devotes a column or a page to exchange material bringing such ideas to all the employees.

Scarcity in Water Works Field

There are, by the way, very few municipal water or light departments that have newspapers, as was discovered two years ago when an effort was made to build an exchange list for the *Waterlite News.* A letter was sent to every municipal water department in the country that was thought large enough to support such an enterprise. Answers were received from most of the departments, but all of them, with a few exceptions, were about the same: "Sorry, but we don't have a department newspaper. We like the idea, however, and would appreciate receiving a sample copy of the *Waterlite News.*" For example, W. Compton Wills of Wilmington, Del., wrote that he was interested in the endeavor, and that he thought publicity of the results should be given in some water works magazine in order that others might know what could be accomplished through such an organ. J. W. Kruse of Lincoln, Neb., wrote that this type of inter-departmental news appealed to him very much and asked for information on publishing such a paper. In fact, in January, 1939,

the Lincoln water and light department began publication of *The Water-Lite Lowdown*, "Newsy, but not Nosey," edited by Mr. Kruse. D. M. Sullivan of Boston wrote that he would be glad to see a copy of the *Waterlite News*, but that there was no newspaper connected with his department. R. W. Furman of Toledo wrote that he favored the plan very highly, but that the Toledo Division of Water did not issue a departmental paper. W. Z. Smith of Atlanta wrote that while he realized the value of published information, his city was not in a position to attempt the undertaking.

Other Department Publications

Colonel Theodore Leisen, at that time general manager of the Metropolitan Utilities District of Omaha, was the first to respond in the affirmative. Omaha has had a department newspaper for over 12 years, and "it's still going strong," so the *Muny Ups and Downs* of Omaha exchanges with the *Waterlite News*. In January, 1940, the water and light department employees of Kansas City, Kan., began publication of *The Kilowatt*. This, together with the previously mentioned *Water-Lite Lowdown* and *Your C-L News*, published by the city light department of Seattle, Wash. constitutes our present exchange list in the field. (Since this paper was presented, the following news sheets have been added to the *Waterlite News* exchange list: *Splashes*, of the East Bay Municipal Utilities District at Oakland, Calif.; *The Kilowater Account*, of the Knoxville, Tenn., Electric Power and Water Board; and the *Siphon*, of the Engineering Club of the Department of Water Supply, Gas and Electricity of New York City.)* Many of the water and light departments publish consumer bulletins and various kinds of reports to the city officials, but these contain no news items about the water and light departments themselves and about the people in them. It is sincerely hoped that this paper will start other departments thinking and acting along the lines of publishing a department news-sheet. Getting some one who is interested in writing to work on the paper is not a difficult problem. Many people like to try their hands at writing and are only too glad to be given the opportunity. The big problem will be to find the time to devote to the writing and editing and publishing, although most people who like to write can do it quickly and although they may like to do it on their own time or when the work in the department is not pressing.

* Mention should also be made of the *Intake*, published monthly, since 1924, by the Los Angeles Department of Water and Power.

Organization of Editorial Staff

Water or electric departments are usually subdivided into smaller divisions such as repair shop, meter shop, drafting room, pumping station, filter plant, distribution, new construction, service, general office, and perhaps new business. These divisions suggest the possible break-down of the editorial staff of the paper. A reporter for each division should be chosen from among the people in the division; after all, a person knows more about his own department than an outsider or some one in another department. The *Waterlite News*, for example, has ten associate editors from ten divisions of the department: water works and new business, reported on by the secretaries of the respective superintendents; water purification plant, power plants, service department, and collection division, all reported on by the men in charge of the division; commercial office reported on by a stenographer; engineering department reported on by the draftsman; and light and power reported by one of the engineers. The Waterlite Employees Association also has its own reporter.

An editor is necessary to head the group, to collect the material, to write or rewrite articles, to edit (of course), and to do anything else that must be done. Some people just seem to fit into such a position; some may have had experience on other papers; and some may have to be guided and directed into becoming an editor. Every department usually has at least one man who can do the work. It just happens that the editor of the *Waterlite News* is listed, officially, as a research engineer.

Besides the editorial staff, the staff of the *Waterlite News* includes two mimeographers, an art editor, a stencilographer, and a business circulation manager. The mimeographers are listed as clerks in the accounting division, the art editor is a clerk in the collection division, the stencilographer is a clerk in the general office, and the business manager is a clerk in the public relations division. Each one does the *News* work in his spare time or when he isn't busy, although the editor usually considers the *News* work a part of his regular duties. Staff meetings are held occasionally, but there is no definite meeting time. The responsible head of the department acts as adviser; everything for the paper (usually) goes through his hands. Obviously, he must guide the policy of this activity just as he guides all other department activities.

Time of Issue

The time of issue of a department news-magazine may be whenever practical. It depends on the size of the department, on the ability of the staff to get news or to write articles, and on the size of the paper itself. The larger the department, the greater the possibilities of things happening and the wider the interests of the department as a whole. The larger the news-sheet, the harder it is to fill, but also the greater the variety of material that it can contain.

The best time to distribute the paper is on payday. Everyone comes to one of the offices for his check, so it is quite convenient for him to get his paper then, too. The *Waterlite News*, for example, comes out on the fourth of the month, one of the semi-monthly paydays.

In the past there has been serious consideration of changing the whole set-up. Instead of a 16-page magazine once a month, an 8-page magazine twice a month, or even a 4-page weekly, was considered. A weekly paper would contain strictly news material, which would really be news. Coming events could be forecast and played up for the coming week and past happenings could be discussed while they were still fresh in people's minds. The 4-page paper would, in the long run, be cheaper to put out because a cheaper grade of paper could be used and because there would be no heavier cover pages. It would take less than a fourth of the time that the 16-page format involves, because, for one thing, the reporters would not have to think so long to dig up news, and, in addition, there would be no feature articles to bother about, no large number of printable jokes to hunt for, and no assembling and stapling of a number of sheets.

On the other hand, it was not certain that the reporters would care to worry about the paper more than once a month; their exuberance for writing might rapidly diminish if they were pushed. In the short paper there would be no room for longer informative articles on the new department developments, on local industries or on items of general interest. There would be no room for anything other than news. The weekly paper would become just another sheet; it would be glanced at and tossed aside as are regular newspapers. People would lose interest in it just as they lose interest in anything that becomes commonplace and numerous. But the largest problem would be that of distribution. How could a weekly paper be made available to every one in the department conveniently? Many of

the employees do not come to a central office every day, and even if they did, most of them would be in a hurry to get home in the evening and wouldn't bother to take the paper with them. Some of the employees do not work Saturdays and some are on varying shifts. To reach them all, conveniently, seemed to be almost out of the question—except on payday.

An 8-page paper issued on every payday would have no trouble with distribution and it would still maintain the advantages of both a weekly and a monthly paper. News would still be rather newsy and there would be room for longer articles, too. The main difficulty would be the extra work, and expense, involved every two weeks. Once a month isn't so bad; twice a month might become burdensome.

Contents

The *Waterlite News*, still a 16-page monthly paper, is now in its fourth year. It was started in January, 1937, by Miss Bonnie Shuck who was, at that time, secretary to Charles Spaulding. She had the idea to bring before the employees little articles on courtesy and on getting along with each other and with the customers. At about the same time, the department began to receive copies of *Your C-L News* and other industrial house organs. A similar paper for Springfield, to include both courtesy articles and news items, was suggested. Plans were made, an art editor was obtained from among the telephone operators, and the *Waterlite News* was born. Miss Shuck was editor and Mr. Spaulding was adviser. Times changed and the present editor fell heir to the paper in September, 1937, since which time he has carried on.

The usual contents of the *Waterlite News* may suggest ideas to you. At least it will show how the space is used. The cover, a two-color one now, is designed by the art editor in keeping with the general spirit of the month. Page 1 is the editorial page which includes the masthead. Page 2 was for two years an innovation in mimeographed magazines. The year before last it was a birthday page with a $1\frac{1}{8}$ by $1\frac{5}{8}$-inch picture of each employee who had a birthday during the month. During the course of the year each employee's picture appeared in the paper. Everyone in the department learned what everyone else looked like, the inestimable value of which is evident in a department so large. Last year the page contained pictures of new developments in the department and of im-

portant events of the month. The picture page was discontinued for several months because the photographer, who is chief of the lake police, was so busy with policing he had no time to print pictures. The picture page will, however, be resumed.

The next four pages contain nothing but personal items from the water works, electric department, and offices, and a list of electric power cut-overs and disconnects. Two pages next frequently are devoted to a feature article; there have been stories of how people in other parts of the world get their water; one series of stories was on large water and power users in the city; other articles have been about important department developments, such as the recent extension to the power plant. New business, garage and repair shop, home service, and general news pages follow. Page 15 is a page of news items from everywhere, a kind of digest of recent developments in science and industry. A page of jokes and comments completes the magazine. The back cover usually carries a small picture or cartoon to finish the booklet.

Format and Cost

How the news-magazine can be published depends on the amount of money the department cares to spend on such a venture. Printing is most impressive; mimeographing may be cheapest. Printing on good paper includes the possibility of using half-tones at no great additional cost. It is possible, however, to get roto-printing on offset paper that will give a full page of pictures in a mimeographed paper at slight extra cost. Then, too, the mimeographed page may be decorated in any way that the art editor desires; individuality is given the paper that can be had in no other way. The items may be illustrated easily and cleverly right on the stencil; more illustrative sketches are possible than with printing and the sketches may be put almost anywhere. Mimeographing is, of course, out of the question if the department has no mimeograph or does not have access to one. It may, however, be wise to buy one anyhow. A mimeograph machine does have a very real place in a water and light department, especially where a large number of forms are necessary and more expecially when only small quantities of any one form are required. In Springfield, for example, over 500 forms are stenciled and run on the mimeograph, besides various kinds of reports and letters and announcements. The cost of putting out the *Waterlite News* on the mimeograph is only about $6\frac{1}{2}$ cents per

copy; this includes the cost of the covers, paper, picture page, stencils, ink, staples, and extra-time art work. It does not include any labor cost since most of the labor is really done after hours or in slack periods. Without the especially-printed picture page and the extra-time art work, the entire cost of putting out one 16-page copy of the *Waterlite News* is $3\frac{1}{3}$ cents. A complete break-down of costs based on the usual 450 copies published per month is shown in Table 1.

Assembly

The deadline for *Waterlite News* is the twenty-eighth of the month. The material is collected and typed in dummy form by the editor; it is approved by the head of the department and given to the stencilographer. The stencils are proof-read, illustrated by

TABLE 1

Break-Down of Costs per Issue of Waterlite News

ITEM	COST PER ISSUE*	COST PER COPY
Paper, 70-lb. egg-shell book (6.3 reams @ $14.48/15 reams)	$6.08	.0134
Covers, 54-lb. white cover-paper (900 sheets)	4.00	.0091
Stencils, letter-head size (18 stencils @ $3.01/24)	2.27	.0051
Mimeograph ink (1 lb. @ $27.80/12 lb.)	2.32	.0052
Staples (1350 @ $1/5000)	.27	.0006
Picture page (450 roto-print on off-set)	8.50	.0189
Art work (extra, after-hours work)	5.50	.0122
Total	$28.94	.0645

* An issue is 450 copies.

the art editor, and turned over to the mimeographers. The day before the paper comes out is "assembly day"; the mimeographers assort, collect, and staple the sheets into the finished product. The stapling is done, by the way, on a home-made triple-stapler, insuring even stapling. All the publishing work is done from the twenty-eighth of one month to the third of the next. This is not particularly fast, but neither does it allow much time to be wasted.

On payday, next to the check, the *Waterlite News* is most eagerly sought. It is read from cover to cover, and then taken home for the rest of the family to read. It is quoted and discussed, both in the

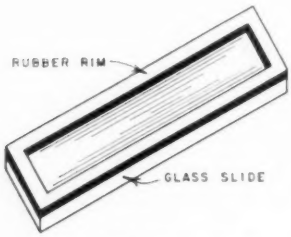
department and out, since we have a mailing list in Springfield of 25 and out-of-town of 50, mostly to water departments in other cities. Everyone enjoys recognition and nearly everyone enjoys reading something about someone else. By presenting little items about people in the department, the employees soon become aware of the other about them, in the next office, at the garage, or out at the plant. It is believed that a community spirit, which can be attained in no other way, is being developed through the *Waterlite News*.

EDITORS NOTE: Readers are urgently requested to write to the author of this paper and to the Editor of the JOURNAL, informing them of other departments which publish a newspaper or periodical. Specimen copies of such publications should be sent to Mr. Bonn and to the office of the Association, so that complete information on the subject may be organized.

Rubber Rim Whipple Cell for Plankton Counts

By A. A. Hirsch

AN INEXPENSIVE Whipple cell for plankton enumeration of water samples may readily be made from an ordinary microscope slide and a sheet of cold patch such as is used for the repair of inner tubes. As shown in the figure, a $\frac{5}{32}$-inch rubber margin is cemented around the edges of the slide after first roughening it to provide a grip. The rubber rim is cut out as a continuous rectangular gasket to avoid corner joints. For a coverslip the usual thin glass or another slide may be used.



RUBBER RIM PLANKTON CELL

Since the volume of the cell will vary with the source of rubber, suitable provision must be made in counting objects. A search of cold patch sheets from six different manufacturers showed thicknesses ranging from 1.09 mm. (Goodrich) to 1.32 mm. (U. S. Tire). Assuming a rim of Goodrich cold patch, the survey and total count multipliers must be reduced by the fraction $\frac{1}{1.09}$ from the figure ordinarily used with the standard 1 mm. glass or metal rim cell. In this particular case, the same result will be obtained, within one per cent error, if nine fields are counted instead of the usual ten. With other samples of rubber gum sheeting, the thickness correction may be calculated from the inverse variation between rim thickness and the magnitude of the multipliers.

As the cost of this type of cell is negligible, an ample supply may be stocked; and important or interesting samples may be preserved by allowing them to dry in the chamber and then filing them as is done with bacterial smears. Rims may be removed and re-used on another slide.

A contribution by A. A. Hirsch, Instructor in Water Purification, State Department of Education, Baton Rouge, La.

The Physiology of Sodium Hexametaphosphate

By K. K. Jones

THE participation of the phosphates in the functions of the cells and the processes of life has been known for a hundred years or more, but a true conception of the fundamental nature of these reactions has been perceived only in the last decade; today we are merely at the threshold of a true understanding of their nature. Known as a chemical curiosity for one hundred years, sodium hexametaphosphate* has but recently been rediscovered to have unique properties that make it of industrial importance and that have suggested far-reaching physiological possibilities.

In order to discuss these possibilities it is important to see the metaphosphates in relation to the activity of the phosphates as a general group in the body. These are found wherever fundamental exchanges of matter and energy take place in the organism. It is interesting to see how the phosphates became so involved in the life of the cell and for this reason let us examine briefly the chemical development of the organism. In broad outline, without attention to details, scientists like Lotka (1), Macallum (2), and others, tell us that life undoubtedly began in the sea, eons ago, when it was not as salty as it is today. The earth at that time was warmer than it is now, and the sky was filled with water vapor. Tremendous electric storms and torrential rains were almost continuous. The atmosphere in these early times contained much more carbon dioxide than it does at this time.

This carbon dioxide dissolved in the water to form carbonic acid, H_2CO_3. The actinic energy of the sun drove two atoms of oxygen

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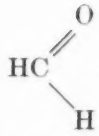
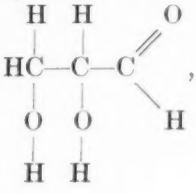
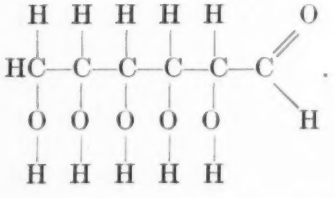
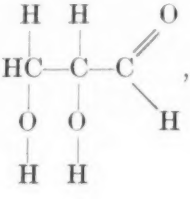
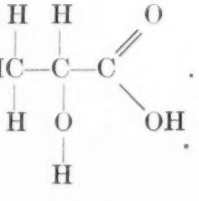
* Hereinafter referred to as hexametaphosphate.

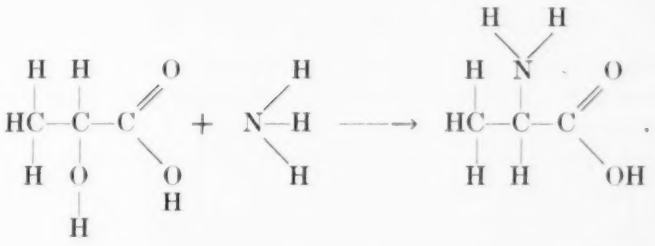
from this molecule, forming formaldehyde,  . In the presence of magnesium salts this formaldehyde condensed to glyceric aldehyde,  , and to hexose and pentose sugar,

 .

Not only could formaldehyde form sugars, but it could condense to aldehyde and aldol and this, in turn, to long carbon chains which lost oxygen and formed fatty acids.

Glyceric aldehyde,  , readily rearranged its atoms and became lactic acid,  .

In the atmosphere the electrical discharges of lightning synthesized ammonia from the atmospheric nitrogen and water, and this ammonia in combination with formaldehyde, through similar condensation, formed the amino acids. For example, the amino acid, alanine, could be formed from lactic acid and ammonia.



With amino acids, fatty acids, and sugars, Nature had building material for the formation of proteins, fats, and carbohydrates, and could begin the process of building protoplasm. Of the intricacies of building protoplasm we know very little, but what we do know indicates that the inorganic ions in the sea water played a fundamental role.

In the same way as magnesium was able to effect a synthesis of sugar, so the other elements in the sea, sodium, potassium, calcium, iron, chlorine, and phosphorus each took part in the formation of protoplasm and became intimately associated with life processes. In fact, many of the synthesized organic compounds were able to combine with different elements or ionic radicals, so that a competition arose between the ions in this regard. Particularly was this true between the active potassium ions and the far more numerous sodium ions. It may even be said that the formation of the cell was an expression of the attempt of the potassium compounds to protect themselves from domination by the sodium ions.

In this struggle for existence the important compounds were the protein molecules. As these various protein molecules grew in complexity, they began to compete for the various amino acids and prosthetic groups from which they could construct their molecules. Out of this competition arose the ability of one protein aggregate to attack and break down another in order to utilize its constituent parts for building material. In other words, enzymes developed.

The calcium ion was utilized by these protein aggregates for its ability to form emulsions with fats that were immiscible in water and that, therefore, could be used to protect the newly forming protoplasm.

For this reason calcium is usually localized in the limiting membranes of the cell and the organism. Iron, because of its great reactivity with oxygen became an intermediary for oxygen transport and found its place in every cell.

Functions of the Phosphate Ion

Around each inorganic ion or radical, therefore, there centered various activities which were peculiar to the chemical characteristics and properties of these elements. Each one is a story in itself, but of all these ions, none assumed a more fundamental role or achieved greater importance than the phosphate ion. We cannot trace the development of these activities but we can list many of the functions:

1. The tri-basic nature of orthophosphoric acid made it possible for mono- and di-basic phosphate salts to be formed. Mixtures of these salts in solution had the property of resisting any change that might take place in the hydrogen-ion concentration of the water in which they were dissolved. Since protoplasm developed only at a neutral reaction, its very formation had to take place in the presence of buffer compounds such as these. For this reason, we see the phosphates as a necessary part of the tissue of all forms of life and a fundamental constituent of the blood of the higher animals.

2. The union of the phosphates with fats made it possible for such phosphorylated fats to become miscible with water; and the union with sugars, to form compounds that could be absorbed through the lipoid membranes of the cell. We have, therefore, phosphorylization as an active mechanism in the absorption of fats and sugars in the intestines and the kidney tubules.

3. Phosphoric acid forms insoluble compounds with calcium and magnesium. When these chemical substances are brought together in a free condition, a precipitate is immediately formed and this deposit in the tissue may become bone, teeth, or shells. In most unicellular organisms the calcium and magnesium are held in solution in the tissue and only coagulate when the tissue is injured.

This coagulation then forms a new membrane. The same mechanism is seen in the coagulation of blood; and the calcification of limiting membrane of cells is shown by the shell of a hen's egg.

4. The phosphate ion, when joined with organic molecules increased the ease with which these molecules could combine with oxygen. The phosphates became necessary to the process by which the cells obtained their energy. Especially true is this in the case of muscle and nerve activity, when sugar, the fuel of the cell, must first combine with phosphoric acid before it can be burned.

We may recapitulate then, that the phosphate radical is fundamentally concerned in the nutrition, the metabolism, the irritability,

and the defense of the cell; and through the cell, of the organism as a whole.

Biological Implications of Metaphosphoric Acids

We now come to a consideration of the biological implications of metaphosphoric acids. Before we can consider this subject it is necessary to review the structure and chemical properties of the phosphoric acids in general, and the peculiar nature of hexametaphosphate in particular. As chemists know, the anhydride of phosphoric acid, phosphorus pentoxide, P_2O_5, combines with either one, two, or three molecules of water. With one molecule of water, two molecules of metaphosphoric acid are formed according to the following equation:

$$P_2O_5 + H_2O \rightarrow 2HPO_3$$

With two molecules of water one molecule of pyrophosphoric acid results:

$$P_2O_5 + 2H_2O \rightarrow H_4P_2O_7$$

With three molecules of water two molecules of orthophosphoric acid are obtained:

$$P_2O_5 + 3H_2O \rightarrow 2H_3PO_4$$

The orthophosphoric acid, therefore, is the completely hydrated form of the acid while the other two acids in solution tend to take up water and change to this form.

Due to the strong hydration capacities of the other two forms of phosphoric acid, the ortho- form is the one found in nature available for synthesis of organic matter. The meta- and pyro-phosphoric acids in solution undergo slow hydration to the ortho- form. This may be of fundamental importance in the biological function of these acids. It is known as reversion and hastened by an alkaline or acid reaction, and a rise in temperature. It is known that this process can be catalyzed by inorganic compounds and Kay (3) has evidence that there is an enzyme in the body able to effect this reversion.

Metaphosphoric acid, because of these strong unsatisfied hydration capacities, can combine with other molecules of itself to form polymers of complex formation, with the general formula $(HPO_3)_x$. The most interesting molecule of this group is the one where six

molecules of the simple acid are united. Commercially, this compound is obtained as the sodium salt, hexametaphosphate, first used for practical purposes by Hall (4).

Properties of Hexametaphosphate

Leaving aside the other physical properties of this salt, it is a colorless, amorphous glass, soluble to the extent of 70 per cent in water. In solution, it has two chemical properties that are responsible for its physiological action. The first is the unique quality of the compound to form a complex with calcium, magnesium, iron, and other di- and tri-valent ions, such that these metals are no longer cations but are combined with the metaphosphate radical as part of the anion. In this form these elements lose all their characteristic properties. For example, calcium in solution as sodium calcium hexametaphosphate can no longer precipitate calcium soap, calcium oxalate, or any other insoluble calcium salt.

The second property of hexametaphosphate, or more properly, of hexametaphosphoric acid, is the ability to combine with protein and, therefore, with tissue. This is shown clearly by the studies of Wilson (5) on the tanning of leather.

Physiological Action of Hexametaphosphate

The action of hexametaphosphate on living tissue arises principally from these two properties, and will be discussed under four headings: (1) the action on blood and circulation; (2) the action on the gastro-intestinal tract; (3) the action on skin and mucosa; and (4) the toxicology.

The action of hexametaphosphate on blood and circulation is first a paralysis of the heart, and then a change in the coagulability of the blood. Both phenomena are caused by the removal of calcium ions from the blood. Since the heartbeat depends on the presence of calcium ions in the blood, the heart dilates and stops when these are removed. When hexametaphosphate is injected into the blood vessels in amounts less than 20 mg. per kilo of body weight no change is noticed in the heartbeat. If an amount varying from 50 mg. to 80 mg. per kilo of body weight is injected, there is a sharp fall in blood pressure with prompt recovery. When 130 mg. per kilo are injected the result is usually fatal. The accompanying Fig. 1 shows that there is first noticed a fall in blood pressure followed by a compensatory rise, then a second fall with total cessation of heartbeat.

That this effect on the heart is due to the removal of the calcium ion by the metaphosphate is shown by the prompt recovery made by the heart when calcium is injected at the same time as the metaphosphate. If 1 mg. of calcium chloride is injected in one vein for every 1.3 mg. of hexametaphosphate injected in another vein, as much as 20 times the lethal dose of metaphosphate can be administered without any effect on the heartbeat or blood pressure.

As previously indicated blood does not coagulate when the calcium ion is removed. Blood serum normally contains 11 mg. of calcium. Of this, 6 mg. per cent is combined with blood protein, 3 mg. per cent is dialyzable but not ionized, and 2 mg. per cent is ionized. The addition of 1 mg. of hexametaphosphate per milliliter of blood

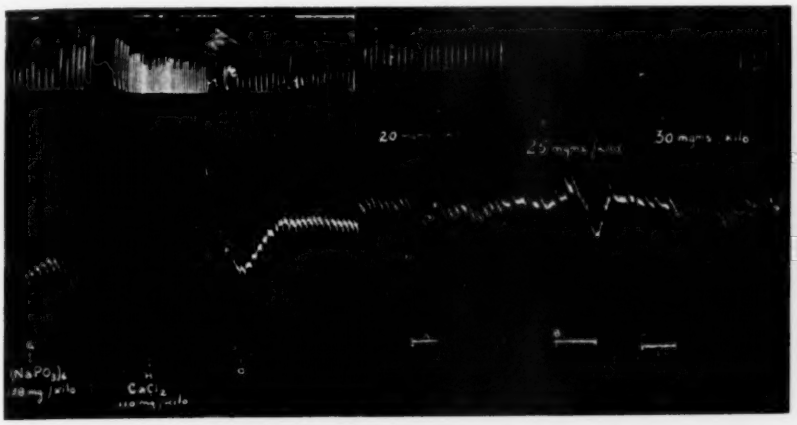


FIG. 1. Effect of Metaphosphate on Heartbeat

effectively removes the free ionized calcium, and the blood remains fluid indefinitely. Klinke (6) states that the greater part of the 3 mg. of non-ionizable calcium migrates to the anode on electrodialysis, and hence, must be in the form of an anion. This suggests the presence of a metaphosphate in the blood serum.

The action of hexametaphosphate on the gastro-intestinal tract is essentially that of the corresponding amount of the orthophosphoric acid when the amount administered is small, since the acidity of the gastric juice brings about a rapid reversion of the meta- to the ortho-acid. When larger doses are given, the hexametaphosphate acts on the calcium ion of the exposed mucosa and causes some irritation of the enteric nerves of the stomach and intestines. The

result of this is vomiting and diarrhea. Since the molecule of hexametaphosphate is large, it is very poorly absorbed, if it is absorbed at all, from the gastro-intestinal tract. In dialysis experiments with animal membranes, the amount of hexametaphosphate that passes as such, is so small that it cannot be detected. Only that phosphate, which has reverted to the ortho-radical can be found. In experiments with dogs, 50 grams have been repeatedly given by a stomach tube, the only result being prompt vomiting, no further injury ensuing. Larger amounts act in this same manner. An ounce of the commercial hexametaphosphate has been taken by man with only a pronounced laxative action being noticed.

In experiments with rats, Murray (7) fed a divided litter of twelve

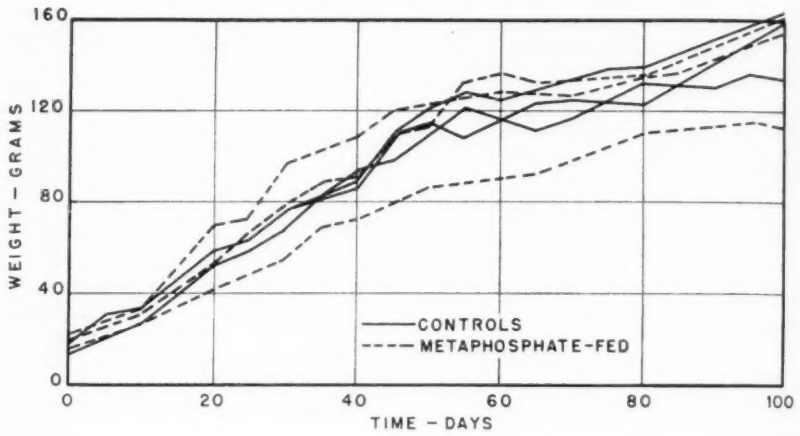


FIG. 2. Growth Curves of Rats

rats on a milk diet. To the diet of six of these he added 20 mg. of hexametaphosphate per day. The other six were kept as controls. After 100 days a pair of rats on the hexametaphosphate diet were mated. A healthy litter of 9 were born and weaned. At the end of this time the rats were autopsied. Neither gross nor microscopical examination of the liver, kidney, heart, spleen, or stomach showed injury or changes. The weight curves are shown in Fig. 2.

Five rats were fed on a diet which contained 5 per cent hexametaphosphate. On this diet the rats ingested 2 grams of hexametaphosphate per kilo of body weight per day. They remained healthy and gained in weight. When the amount of hexametaphosphate was doubled, the rats had a diarrhea for nine days, then recovered, but

did not gain in weight. Autopsy showed no changes, except in the lining of the intestine, which was slightly injected and hemorrhagic.

Fecal and urinary calcium were followed on these animals. The results showed a decrease in fecal calcium and an increase in urinary calcium, with a net retention of calcium. This suggests that hexametaphosphate facilitates the absorption of calcium from the intestine. A summary of these data is shown in Table 1.

TABLE 1

Calcium Metabolism of Rats on Diets With and Without Hexametaphosphate

DAYS	URINARY CALCIUM (MG. DAILY)		FECAL CALCIUM (MG. DAILY)	
	Without hexametaphosphate	With hexametaphosphate	Without hexametaphosphate	With hexametaphosphate
1	0.5852	0.4280	—	—
2	0.3138	0.5825	—	—
3	0.2641	0.3400	—	—
4	0.5905	0.5280	—	—
5	0.2112	0.3748	18.5	3.03
6	0.2280	0.3465	20.3	3.03
7	0.2624	0.2477	26.4	3.04
*8	1.1165	1.7094	24.3	1.47
9	1.2480	Contaminated	25.3	3.60
10	1.2846	3.8746	19.3	2.97
11	1.7386	5.4797	14.7	2.16
12	1.8585	5.4666	16.9	2.34
13	1.7145	5.7865	17.4	2.10

Average daily calcium ingested		22.9 mg.
Average daily urinary calcium	normal	1.5 mg.
	hexametaphosphate	4.5 mg.
Average daily fecal calcium	normal	19.7 mg.
	hexametaphosphate	2.4 mg.
Average net calcium retention	normal	1.7 mg.
	hexametaphosphate	16.0 mg.

* Average calcium retention in the body computed from the last six days after diarrhea had ceased.

The absorption of the hexametaphosphate radical on four bladder-fistula dogs was studied. An increase in urine was shown but no more than an equivalent amount of orthophosphate would have given. This showed that little, if any, unreverted phosphate was absorbed. It was hoped that enough hexametaphosphate might be excreted in the urine to prevent formation of calcium stones in the ureter, but this did not occur.

Experiments by Schwartz, Jones, Mack, and Vance (8) have shown that 40 mg. of hexametaphosphate per 100 ml. of milk, can effectively prevent the coagulation of milk and the formation of curd, just as it can prevent the coagulation of the blood. This is particularly effective because the calcium is not removed from the milk and on digestion of the milk it is made available to the body. Some evidence was obtained in this work that absorption of iron was facilitated by the presence of the hexametaphosphate (see Table 2).

The main action of hexametaphosphate on the skin is again the sequestering effect of this compound on calcium ions. So fundamental is the need for the calcium ion by the body that the effect shows in many diverse and most unexpected ways whenever it is removed. The following phenomena which are affected by hexa-

TABLE 2

Analysis of Rats on Diets With and Without Hexametaphosphate

	TOTAL AVE. CALCIUM IN MG. PER GRAM OF WEIGHT	PROBABLE ERROR	AVE. TOTAL IRON IN MG. PER GRAM OF BODY WEIGHT	PROBABLE ERROR
Control	8.34	±0.198	0.058	±0.0006
Hexametaphosphate	9.20	±0.326	0.067	±0.0023
Hexametaphosphate plus iron	8.20	±0.271	0.120	±0.0024
Iron alone	8.7	±0.205	0.097	±0.0024

metaphosphate may be listed: (1) bacterial infections; (2) invisible perspiration; and (3) regeneration of epithelial tissue.

It has been pointed out previously that the calcium ion has a marked effect on the formation and stability of emulsions in the body. When this ion is in excess a water-in-oil emulsion is formed. When calcium salts are added to oil-in-water emulsions of which the living epithelial cells are a type, this emulsion changes to the water-in-oil type with the extrusion of the excess water. In other words, it is similar to the churning of butter from cream with extrusion of buttermilk. In tissue this becomes fatty degeneration and necrosis. Bacteria of the staphylococci strain can live on the normal, healthy skin without entering the deeper layers and without producing injury. Such bacteria are killed easily by sodium soap. In the presence of an insoluble precipitate of calcium soap formed in hard water, these bacteria have been shown to live for weeks with un-

diminished vigor; therefore, they may be found in calcium soap deposits on the fibers of clothing, as determined by Gilmore (9). Such deposits of calcium soap are insoluble in water but dissolve in the oily secretions of the sebaceous glands.

We have found that when non-virulent bacteria are mixed with calcium soap and rubbed into the hair follicles, infections are obtained where they cannot be obtained by rubbing the same bacteria into a clean skin (10).

The calcium soap, therefore, produces tissue injury which permits the bacteria to grow. Hexametaphosphate, by dissolving calcium soap, prevents this entrance of bacteria into the skin and also exposes the bacteria on the skin to the destructive action of sodium soap.

Hexametaphosphate, in acid reaction, has the ability to attach itself to the protein of the skin in a more or less stable bond, depending on the pH. At a strongly acid reaction, Wilson (5) has shown that metaphosphoric acid can tan the skin. Schade and Marchionini (11) have found that normal cornified epithelium has a pH of 3.5 to 4.0. At this reaction the hexametaphosphate molecule attaches itself to the cornified layer of skin as a very thin, protective layer. It is not known whether it is due to this protective layer on the skin, or to the effect on the nerves of the skin, but experiments have shown that an application of 10 per cent hexametaphosphate will decrease the insensible perspiration by an average of 50 per cent on the resting individual at normal room temperature.

Experiments on staphylococci show that in amounts from 0.5 to 3.0 per cent hexametaphosphate agglutinates bacteria and prevents their growth but does not kill the organisms. When the cultures stand for several days and reversion to orthophosphate occurs, the bacteria again grow. The effect on isolated epithelial cells is much the same as on bacteria; but on cells attached to the body, the impermeability of the cell for the hexametaphosphate precludes any harm to the cell. Weak solutions of hexametaphosphate, therefore, are able to surround these cells with a definitely bacteriostatic and at the same time harmless environment. Placed on superficial wounds of skin or infections of mucosa, a definite prophylactic effect is obtained. Five to ten per cent solutions of hexametaphosphate are therefore of definite value in the treatment of sore throat, abrasions of the skin, first degree burns and the ordinary infections of daily life.

One point, however, in this regard needs to be considered. The injection of hexametaphosphate solutions into the skin, removes calcium from the nerve endings and throws these nerves into a state of excitation which is shown by the keen, exquisite pain experienced and by the scarletiform eruption that appears along the course of the irritated nerve. This pain makes it impossible to use the hexametaphosphate over large areas of exposed nerves where its bacteriostatic properties would be most useful otherwise.

A discussion of the toxicological properties of hexametaphosphate is rather misleading for in the usual meaning of the word, and in amounts commonly administered, none of the phosphates are toxic. Starkenstein (12) has shown that in the rabbit, the average limit to a safe dose for oral ingestion is: orthophosphate, 15 grams; pyrophosphate, 3 grams; and metaphosphate, 4 grams.

Fifteen grams of metaphosphate by stomach tube, when administered to a dog, cause vomiting, but when the same amount is given in the food it is well tolerated.

If the same ratio which obtains for the rabbit would hold for man the figures would read: orthophosphate, 450 grams; pyrophosphate, 90 grams; and metaphosphate, 120 grams.

On intravenous injection the minimal lethal dose is as follows:

		Mg. per kg.	Amount in grams per 60 kg. man
Sodium orthophosphate	Na_2HPO_4	4250	255
Sodium pyrophosphate	$Na_4P_2O_7$	70	4.2
Sodium metaphosphate	$(NaPO_3)_6$	130	7.80

From this, it can be seen that the toxicity of hexametaphosphate is low, for man could not tolerate 120 grams of table salt by mouth any more satisfactorily, nor could he tolerate 8 grams of table salt intravenously.

Conclusions

1. The phosphate ions are fundamentally involved in the formation of protoplasm and the origin of life.

2. The phosphates regulate neutrality of blood and tissue fluids; make the absorption of nutrients from the gastro-intestinal tract possible; regulate the oxidation of sugar in the muscle; and make possible the formation of bone and teeth.

3. The hydration capacities of the meta- and pyrophosphates suggest a mechanism that may be utilized by the body, but it is

unknown at present. That this may occur is indicated by the ability of tissue enzymes to cause reversion of pyro- and metaphosphate.

4. Hexametaphosphate, because of its large and non-absorbable molecule, and because of the rapidity with which its reversion is brought about in the stomach, is relatively non-toxic when taken by mouth.

5. Hexametaphosphate has two actions: it combines with the calcium ion to form a non-ionized, soluble compound; and it combines with skin or mucosa to form protective films. These properties of hexametaphosphate may be used to: inhibit the heartbeat; prevent the coagulation of milk or blood; remove calcium soap deposits from hair and skin, and thereby prevent possible infection; and form protective films on skin and mucosa.

6. Hexametaphosphate is no more toxic than any physiologically active salt.

References

1. Lotka, Alfred G. *Elements of Physical Biology.* Williams & Wilkins, Baltimore (1925). p. 204.
2. Macallum, A. B. The Origin of the Inorganic Composition of the Blood Plasma. Report Brit. Assn. Adv. Sci. **80:** 765 (1910).
3. Kay, H. D. The Phosphatases of Mammalian Tissues. II. Pyrophosphatase. J. Biochem. **22:** 1446 (1928).
4. Hall, R. E. U. S. Patent 1,903,041 (1933); U. S. Patent 1,956,515 (1934).
5. Wilson, John Arthur. The Electronic Theory of Tanning. V. Phosphate Tanning. J. Am. Leather Chem. Assn. **32:** 113 (1937).
6. Klinke, Karl. New Contributions to the Question of the Calcium Condition in the Body. Biochem. Z. (Ger.) **213:** 177 (1929).
7. Murray, D. E. Contributions to the Physiology and Pharmacology of Sodium Hexametaphosphate. *Thesis.* Northwestern Univ. Med. School, Chicago. (1937).
8. Schwartz, Charles, Jones, K. K., Mack, T. W. and Vance, R. W. The Use of Sodium Metaphosphate for the Preparation of Soft-Curd Milk. Jour. Dairy Sci. **23:** 19 (1940).
9. Gilmore, Bernard H. The Determination of Calcium Soap on Textile Fibers. Am. Dyestuff Reporter. (Nov. 19, 1934).
10. Jones, K. K. and Lorenz, Marie. Unpublished Observations. Northwestern Univ. Med. School, Chicago.
11. Schade, H. and Marchionini, A. On the Physical Chemistry of the Skin Surface. Arch. Derm. u. Syph. (Ger.) **154:** 690 (1928).
12. Starkenstein, Emil. Ionic Action of Phosphoric Acids. Biochem. Z. (Ger.) **32:** 243 (1911).

Corrosion Control by Sodium Hexametaphosphate

By H. T. Gidley and Robert Spurr Weston

THE Fairhaven Water Company, organized by Joseph K. Nye, its first President and Superintendent, was incorporated in 1888, and started serving water in 1893. It was financed by the late Henry H. Rogers, who donated many of the public buildings in the town, including the Millicent Library. When the water company was a going concern all of its stock was turned over to the library, which has owned it ever since.

Fairhaven is located on Buzzards Bay in southern Massachusetts. Its population is about 12,000 and its average rate of water consumption about 450,000 gallons per day.

The Fairhaven Water Company now supplies the town with ground water from two stations, each pumping from thirty-odd driven wells. The Nasketucket Station is about a mile from the center of the town, and the Mattapoisett Station two miles farther away on the same supply main. The former station is used mostly during periods of higher consumption demand. Figure 1 shows the general location of the works.

Some trouble had been experienced with red water in dead ends and where two dissimilar metals were connected in services of dwellings. Most of the trouble occurred where galvanized iron joined brass or copper pipes or fixtures. There was also a considerable accumulation of ferric hydrate in the distribution system and this appeared occasionally, especially at times of excessive draft.

Inspection of disks cut from the mains showed little or no evidences of corrosion. Tubercles were absent, and the powdery coating of

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rust when brushed off showed that the underlying pipe coating was in good condition.

Yellow brass pipe corroded also. Several samples collected from various piping systems in the town were examined by the Massachusetts Department of Public Health. Its report states that "all samples were badly corroded and that cross-sections of the pipe showed de-zincification which had started on the inner surfaces of the samples and spread towards the outside"; and that "the yellow color was changed to brown as the zinc was dissolved away and the brass

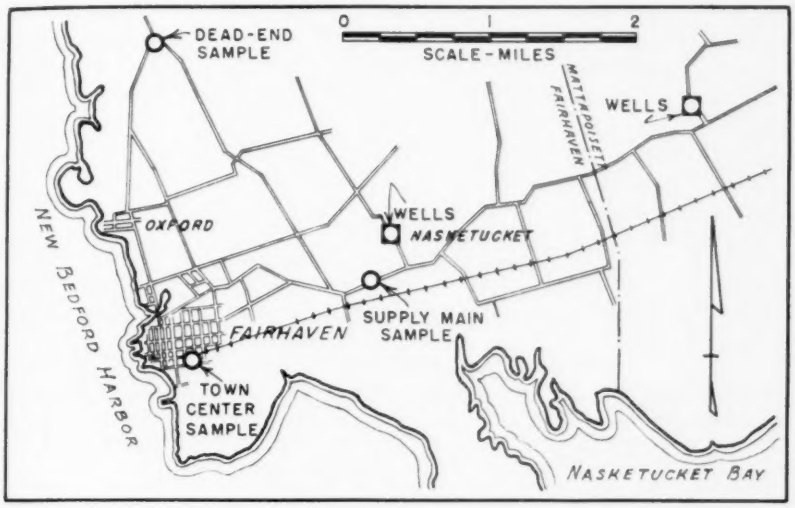


FIG. 1. General Location of Works

replaced by a more or less porous (weaker) copper structure." Table 1 shows the results of analyses illustrating this condition.

On November 7, 1938, a sample had been collected from a lead service connected with copper house piping. This combination, dangerous because of the electrolytic action between dissimilar metals, was only two years old, and with many waters would have resulted in solution of much lead, followed by lead poisoning. In this case, however, only 0.08 p.p.m. of lead was found even under condition of standing overnight before drawing the sample, while only 0.02 p.p.m. was found under conditions of ordinary use—both amounts being well below the accepted safe limit of 0.10 p.p.m. The

results were all the more surprising because the water is acid and contains over 30 p.p.m. of carbon dioxide, with a low pH value—5.6.

Careful observation has shown that while some of the newer galvanized iron tanks and galvanized iron piping in the houses of low cost show some effects of corrosion, those in the older and better built houses do not.

TABLE 1

Results of Analyses of Samples of Brass Pipe
(Department of Public Health)

DETERMINATION	INSIDE	OUTSIDE
	%	%
Copper	75.6	60.0
Zinc	21.1	39.0
Lead	Trace	Trace
Iron	Trace	Trace

TABLE 2

Results of Analyses of Samples

POINT OF SAMPLING	TEMP.	CARBON DIOXIDE	DISSOLVED OXYGEN		pH	IRON
	°F.	p.p.m.	p.p.m.	% Sat.		p.p.m.
Mattapoisett Sta.	50.0	28.0	5.2	46.0	5.3	0.15
Nasketucket Sta.	55.4	32.4	2.0	18.9	5.6	0.90
636 Washington St.		27.6			5.3	0.24
Union St.	60.8		4.6	46.3		
86 Chestnut St.		31.8			5.5	0.05
74 Green St.		30.0			5.4	0.15
32 Fort St.	65.3		3.6	36.0		
32 Linden St.		23.4				0.20
2 Taber St.		31.0			5.5	2.60
477 Main St.	59.0	27.0	0.0	0.0	5.6	0.15
Office, Bridge St.	61.7	29.7	4.1	42.4	5.4	0.05

Quality of Fairhaven Water

In a comprehensive survey and valuation of the Fairhaven works, Frank A. Barbour, Civil Engineer of Boston, observed this corrosive action, and also that the average water supplied from the two stations contained an average of 30 p.p.m. of carbon dioxide and had a low pH value of 5.4. He recommended treatment to correct the unfavorable condition. In accordance with his advice, Weston &

Sampson, Consulting Engineers, were retained for a study of the problem, and beginning on June 2, 1939, inspected the works and analyzed samples of water from various points. Results of the analyses are given in Table 2.

The lower dissolved oxygen in the Mattapoisett water is in keeping with the lesser effect of surface water.

The disappearance of the oxygen at 477 Main Street, a dead end near Acushnet, indicates that some of the iron has oxidized and settled out in the pipes as ferric hydroxide (rust).

The amount of iron found in the water, however, was low, as it was nearly everywhere in the system except on Taber Street where there was evidently an accumulation of "red water" in a dead end.

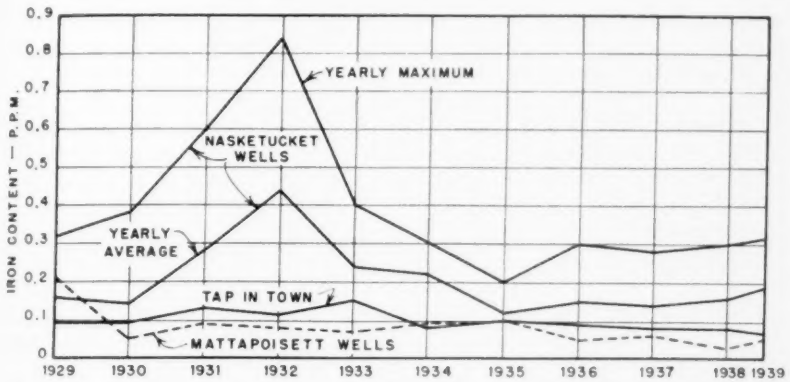


FIG. 2. Iron Content of Water From Wells and Taps in Town, 1929–39

Because the pumps at the Nasketucket Station had been started only a short time before the sample was taken, the iron found was far above normal.

Plotted on a diagram (Fig. 2) are the results of determination of iron made by the Department of Public Health during the past eleven years, namely, the yearly averages and maxima for the Nasketucket wells, and the yearly averages for the Mattapoisett wells and the tap in town from which the samples were taken regularly. From this it will be seen that at no time has the yearly average amount of iron found in the tap in town exceeded 0.15 p.p.m. This is well below the usually accepted safe limit of 0.30 p.p.m. Furthermore, the figures show a maximum of only 0.22 p.p.m. in the whole period

It is also evident that the amount of iron in the Mattapoisett well water has averaged less than that in the tap sample, and the maximum during the period was but 0.52 p.p.m.—during the first year of pumping (1929). It reached 0.40 p.p.m. in 1935, and the highest in the remaining years was 0.20 p.p.m.

The averages of results of analyses by the Department of Public Health and by Weston & Sampson during 1938 and 1939 are shown in Table 3.

TABLE 3

Averages of Results of Analyses During 1938–1939

DETERMINATION	MATTAPOISETT WELLS		NASKETUCKET WELLS	
	1938	1939	1938	1939
Color, *p.p.m.*	1	1	31	28
Free Ammonia, *p.p.m.*	0.001	0.004	0.006	0.190
Albuminoid Ammonia, *p.p.m.*	0.013	0.012	0.053	0.072
Nitrogen as Nitrates, *p.p.m.*	2.00	0.80	0.47	0.37
Nitrogen as Nitrites, *p.p.m.*	0.000	0.000	0.000	0.000
Residue on Evaporation, *p.p.m.*	69.	176.	69.	68.
Chlorides, *p.p.m.*	14.5	73.4	8.9	10.4
Hardness, *p.p.m.*	28.	39.	28.	37.
Alkalinity, *p.p.m.*	9.	9.	13.	15.
Carbon Dioxide, *p.p.m.*	—	28.0	—	32.4
Dissolved Oxygen, % *Sat.*	—	34	—	19
pH		5.3		5.6
Temperature 6/7/39, °*F.*		50.0		55.4
Temperature 11/39, °*F.*		59.0		—

Fairhaven is a coastal town; consequently the flood wave of sea water during the hurricane in September, 1938, affected the composition of the Fairhaven ground water supply. This is shown by the results of partial analyses of samples collected on June 7, 1939 (Table 4).

It will be noted that the color of the Nasketucket water was much higher than the average for 1938, while the residue on evaporation was about five times as high. The increase in the residue on

evaporation and the total solids in the water from the Mattapoisett wells is also striking. The hardness was increased over threefold. The amounts of calcium, in the Mattapoisett water at least, indicate a hardness due in part to sulfates derived from sea water. This abnormal condition was gradually overcome by the flow of land water, and present conditions may be considered normal.

All the evidence showed that for some reason—perhaps its content of calcium silicate—the Fairhaven water is less aggressive to metals,

TABLE 4

Results of Partial Analyses of Samples, June 7, 1939

DETERMINATION	NASKETUCKET WELLS	MATTAPOISETT WELLS
	p.p.m.	*p.p.m.*
Color	85	0
Oxygen consumed	8.70	—
Total residue on evaporation	161.	344.
Mineral residue on evaporation	55.	193.
Loss on ignition	106.	151.
Alkalinity	10.	12.
Hardness	46.	86.
Calcium	20.	30.

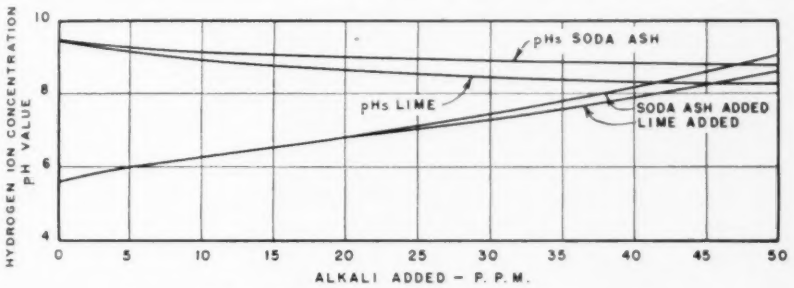


FIG. 3. Effect of Addition of Alkali on pH and pHs

with the possible exception of yellow brass, than most waters of the same type.

To determine the amounts of alkali required to saturate a water and make it non-corrosive, the calculation of the Langelier coefficient (pHs) is usually in order (1). The results of this calculation are shown in Fig. 3.

On the same diagram are plotted the relative increases in pH value for various additions of lime or soda ash as determined in the labora-

tory. Where these respective curves cross each other are the points corresponding to doses of lime or soda ash required to saturate the water. These show that 45.8 p.p.m. of lime or 47.0 p.p.m. of soda ash would be required and these doses would raise the pH values to 8.3 and 8.8, respectively—with a corresponding high increase in hardness in the case of lime.

Experiments With Metaphosphate

Because the studies showed that the addition of the usual lime or soda ash would reduce corrosion but slightly and would increase the deposition and accumulation of iron hydroxide in the system, with the resulting "red water" troubles, it was decided to recommend the use of sodium hexametaphosphate,* $(NaPO_3)_6$. This chemical has been used for about three years to prevent precipitation of calcium carbonate in distribution systems supplied with softened water (2).

Because it was claimed that one part of metaphosphate would hold four parts of iron in solution, and would also reduce the corrosive action of the water, and because no results of the trial of the chemical, in a similar case, were on record, arrangements were made for a test at the Mattapoisett Station. The apparatus consisted of two pairs of tubes; the first one of each pair was filled with steel wool or a mixture of steel and copper wool supported on a thin layer of glass wool, and the second one with small glass beads similarly supported.

Raw well water and the same treated with 2 p.p.m. of metaphosphate were passed through the metals and beads in succession, and the results noted.

The weight of metallic wool was about 12 grams (0.44 ounce) and the rate of application was 0.3 liter (0.32 quart) per minute, a ratio of metal surface to water far beyond anything to be found in practice.

The first run, on June 27, lasted three hours, at the end of which the steel exposed to the raw water had slightly darkened, the glass wool supporting the steel wool had a distinct brownish appearance, while the beads in the tube beyond were slightly brownish. No change was noticed in either steel or beads exposed to the water treated with metaphosphate.

After standing overnight, the steel wool in both setups was slightly darkened but neither had rusted. There was, however, a slight layer

* Hereinafter referred to as metaphosphate. The metaphosphate referred to in this paper is the commercial product known as "Calgon."

of rust on the bottom of both tubes containing the steel wool. The beads in the untreated water test had a distinct brownish discoloration in the upper $\frac{1}{4}$ in., while in the treated water test they were unchanged and clean.

To emphasize the effect of the metaphosphate, another run of three hours' duration was made with a mixture of steel and copper wools, with the idea of accelerating corrosion of the steel wool by the electrolytic action between the dissimilar metals. This test showed

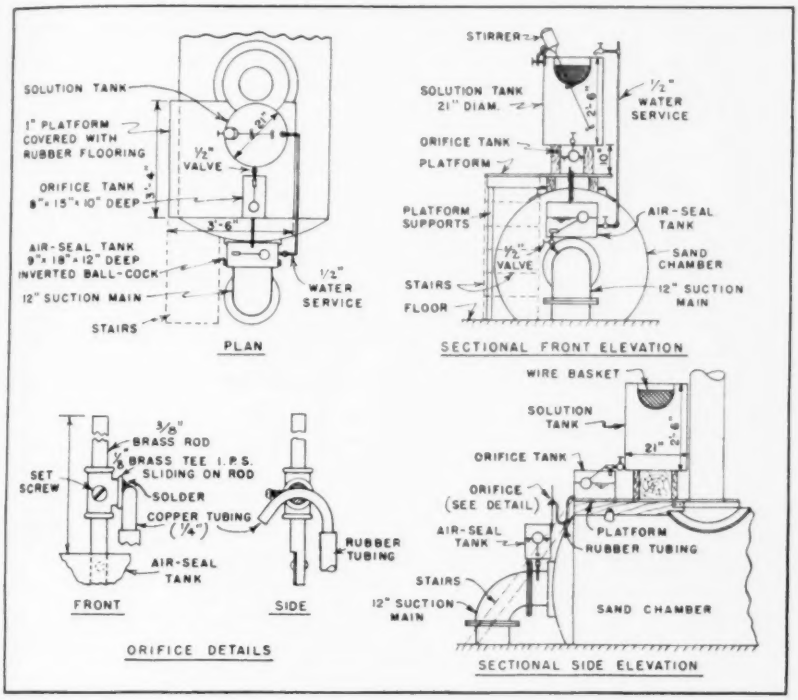


FIG. 4. Chemical Treatment Equipment for Mattapoisett Station

distinct action with the raw water and none with the treated water. On removing the wools from the tubes a decided deposition of rust was found in the mixture of wools exposed to the raw water and only a slight deposit in the one exposed to the treated water.

Following the promising results of experiments, arrangements were made to apply 1 p.p.m. of metaphosphate to the town water. This was applied to the suction main where it entered the sand catcher at the Mattapoisett Station. The devices used are shown in Fig. 4.

Results of Application

The first effect of treatment was purgative. Accumulated iron oxide sloughed off the mains and red water became a frequent occurrence at dead ends. Conditions were controlled by careful operation until this effect ceased to be important.

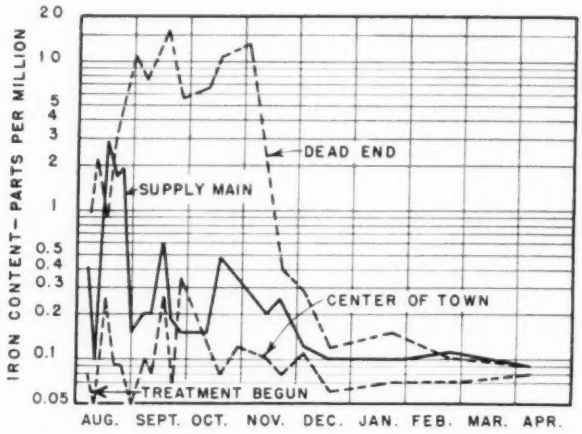


FIG. 5. Effect of Treatment with Metaphosphate

TABLE 5

Results of Analyses on Samples Collected April 11, 1940

DETERMINATION	SUPPLY MAIN	TAP, CENTER OF TOWN	DEAD END
Color, *p.p.m.*	5.0	5.0	5.0
Turbidity, *p.p.m.*	0.0	0.0	0.0
Alkalinity, *p.p.m.*	9.0	10.0	11.0
Carbon Dioxide, *p.p.m.*	52.0	51.0	44.0
Iron, *p.p.m.*	0.09	0.08	0.09
pH	5.6	5.6	5.8

Samples were collected from the treated well water, a tap in the center of the town, and a tap on the worst dead end in town, that is at the end of a long 8-inch main running to the northerly (Acushnet) line nearly six miles from the Mattapoisett Station. The locations of these sampling points are shown on Fig. 1.

The results of treatment, as shown by the samples from these stations, have been plotted on a diagram (Fig. 5).

Before adding metaphosphate, a set of samples showed 0.40 p.p.m. of iron in the well water, 0.08 p.p.m. in the center of town, and 0.95 p.p.m. in the dead end. After six weeks, the amounts of iron increased to 0.60, 0.27 and 16.0 p.p.m. at the respective points. Shortly afterwards, conditions began to improve. The amounts of iron gradually decreased until on February 28, 1940, they were 0.11, 0.07 and 0.10 p.p.m., respectively.

That conditions are now satisfactory is shown by the results of analyses of samples collected on April 11, 1940 (Table 5).

To save work and because it was believed that there could be little change in iron content between the wells and the sampling point on the mains, no determinations of iron in the untreated well waters were made by the writers. Two sets of determinations, however, were made by the Department of Public Health and their results

TABLE 6

Iron Determinations by Department of Public Health

DATE, 1940	IRON–*p.p.m.*				
	Mattapoisett Wells	Nasketucket Wells	Supply Main	Center of Town	Acushnet Dead End
January 15	0.10	0.70	0.10	0.06	0.14
March 19	0.03	0.15	0.099	0.072	0.097

may be compared with those of analyses of samples from the supply main, as shown in Table 6.

The high iron in the Nasketucket sample on January 15 is probably due to the fresh start of the pumps which are not kept in continuous service during the winter as are those at the Mattapoisett wells. On June 2 following another starting of the pumps the water from these wells contained 0.9 p.p.m. which is far above the yearly average of less than 0.2 p.p.m.

On March 19 when both well systems were in service the amount of iron in the water at the wells averaged 0.09 p.p.m. and at the supply main 0.099 p.p.m. The variation between these results is within the limits of error of analysis.

To explain the purgative action is difficult. The best explanation is offered by Langmuir; namely, that a film one molecule thick is formed on the metal and inhibits corrosion. It may be true, also, that the effort required to place the film loosens the accumulated ferric

hydrate. It is true that a recent trial with a soft surface water of low color exhibited the same purgative effect on old deposits.

While the theoretical explanation is difficult, the results show that after eight months of operation, the iron content in the sample from the worst dead end has been reduced from 0.95 to 0.09 p.p.m., or 91 per cent, while the color has been reduced from 29 to 5, or 83 per cent. It is hoped that the future will show a continuance of this good condition.

References

1. Moore, Edward W. Calculation of Chemical Dosages Required for the Prevention of Corrosion. J. N. E. W. W. A. **52:** 311 (1938).
2. Rice, Owen, and Hatch, G. B. Threshold Treatment in Municipal Water Supplies. Jour. A. W. W. A. **31:** 1171 (1939).

Notes on Corrosion Prevention by Sodium Hexametaphosphate

By Edward C. Trax

THE value of sodium hexametaphosphate* for the stabilization of waters softened by the lime-soda ash process and for the prevention of after-precipitation of calcium carbonate has been reasonably well established during the past two years. This application also includes the treatment of waters where lime is used to increase the pH value for corrosion prevention and has proved valuable in preventing the deposition of calcium carbonate in inconvenient places throughout the water plant and distribution system. The method has an important advantage over the recognized procedure of recarbonation in that it permits carrying as high a pH value as desired in the finished water and thus delivers a water as nearly non-corrosive as is possible with chemical treatment.

It has been observed in laboratory experiments that if sufficient metaphosphate is added to waters with pH values ranging as low as 6.0, corrosion of iron and steel can be almost entirely prevented. This has led to the experimental treatment of certain waters on a plant scale without adjustment or increase of the pH value.

Two instances of the application of metaphosphate solely for the prevention of corrosion have come within the writer's observation during the past year.

In the first instance, severe corrosion was taking place in the pasteurizer for bottled beer in a brewery. The link belt operating mechanism and all steel parts of the pasteurizer were rusting very badly, and there was so much iron sludge in the hot water that a troublesome deposit was left on the bottles after pasteurization.

A paper presented on April 24, 1940, at the Kansas City Convention by Edward C. Trax, Chemist, Filtration Plant, McKeesport, Pa.

* Hereinafter referred to as metaphosphate. The metaphosphate referred to in this paper is the commercial product known as "Calgon."

The use of two parts per million of metaphosphate eliminated this trouble entirely, and no further corrosion is taking place.

In the second instance severe corrosion occurred throughout the distribution system of a water company supplying a widely scattered territory in Western Pennsylvania. Because of some peculiarities and unusual conditions in connection with this supply, a very brief description of the water works system seems necessary. It was originally built to supply water almost entirely for industrial purposes in connection with the bituminous coal and coke industries. The water was used largely for steam boiler purposes and for quenching coke made in beehive ovens. A maximum of seven million gallons per day was furnished at one time, a small amount of this being used for domestic purposes in the communities built up around the mines and coke ovens. With the decline of mining operations and the coke industry in the district, the industrial consumption has dwindled to a very small amount, and during the past year the output of the plant has averaged less than 2 m.g.d., the greater part of which is now used for domestic purposes. Originally the demands for water at the mines and coke ovens were variable and exacting and the supply lines are quite large, which results in a sluggish flow with the diminished use of water at the present time.

The water supply is taken from the Youghiogheny River about sixty miles above Pittsburgh and was furnished, from 1894 until 1917, without any treatment, except chlorination, which was started about 1911. From 1917 until May 1, 1939, soda ash was fed directly into the water as it was pumped to the reservoir and distribution system. The river water at this point is polluted to some extent with acid-iron drainage from coal mines and at times of low flow may contain free sulfuric acid and as much as 5.0 p.p.m. of iron. Over this period the active corrosion in the supply lines and distribution system, in addition to the deposits in the lines brought about by the soda ash treatment, caused some red water troubles but not to the extent that might have been expected as long as a large flow through the system was maintained. The water was generally soft and not unsuitable for the principal purposes for which it was used. As the industrial use of water diminished and the domestic consumption increased in amount and importance, the water company felt obligated to furnish a better water for this purpose, and a year ago installed a modern filtration plant. The water leaving this plant has been uniformly clear and sparkling, practically free from iron

at all times, with a pH value adjusted by lime treatment to 9.4 to 9.6, and a total alkalinity of 12.0 to 14.0 p.p.m.

Prior to the introduction of filtered water, the supply lines and most of the distribution lines were cleaned mechanically. Almost immediately after filtered water was turned into the system, most severe red water troubles developed. Complaints poured in from most, but not all, of the communities supplied and analyses of the water showed excessive amounts of iron, ranging as high as 29.5 p.p.m. in some parts of the system. Further investigation showed that this trouble was due to both active corrosion and to the solution or softening of some of the deposit in the lines that had not been cleaned, or in lines where some of the deposit had escaped the cleaning process. It was evident that active corrosion was taking place in the large supply lines, with a reduction in pH value which tended to make the water a better solvent for the deposit with which it later came in contact.

Application of Metaphosphate

In order to check the serious corrosion as quickly as possible, the pH value of the water was immediately increased to 10.2 by additional lime, fed into the filtered water. This checked the severe corrosion very quickly but naturally resulted in excessive deposits of calcium carbonate in the clear well, transmission line, and reservoir. Metaphosphate, at the rate of 20 p.p.m., was then applied to the water in the clear well and a quick clearing up of the condition resulted. After two weeks the dosage was reduced to 1.0 p.p.m. and was applied to some extent intermittently until last November, the pH value of the water being maintained at 10.0 to 10.4. Beginning November 1, the metaphosphate treatment was increased to 4.0 p.p.m. for seven days, then 2.0 p.p.m. for the next seven days, and then continued at the rate of 1.0 p.p.m. to the present time. The pH value of the water has been reduced to 9.4 and maintained at this point during the past four months. All of this has been partially, but not completely, successful and red water troubles flare up from time to time in some parts of the system. It is believed, however, that active corrosion has been entirely checked and that the trouble now comes from the continued sloughing off of the deposit in the lines. This is about the only conclusion that can be reached at the present time, and this condition is being relieved by systematic and continued flushing in the districts where the trouble occurs.

Progress Report on the Use of Sodium Hexametaphosphate at Garden City, N. Y.

By Allan H. Rogers

THE municipal water system of Garden City serves a population of about 11,000 through 65 miles of mains and 2,700 services. The supply is obtained from six wells of varying depth located in a well field immediately adjacent to the water pumping station. All water is aerated through spray heads entering the storage tank, from which two supply mains leave in opposite directions. Pumpage varies from a minimum of one million gallons per day to a maximum of almost four million gallons per day.

In common with other Long Island waters, the supply is at least moderately corrosive. The pH value ranges from 5.3 to 6.1, with an average value of about 5.8. Free carbon dioxide in the well water ranges from 20 p.p.m. to as high as 43, and averages about 28. This is subsequently reduced by aeration to around 12 p.p.m. Iron does not exceed 0.2 p.p.m., total hardness averages 10 p.p.m. in the deep wells and 60 in the shallow wells, with alkalinity ranging from 2 to 15 p.p.m.

Corrosion prevention has been studied for a number of years. While no general complaints as to discoloration of water delivered to consumers have been received, it has been necessary, of course, to flush dead-end hydrants regularly, and in recent years a number of cross mains have been constructed to improve circulation. Complaints have been made principally on the necessity of replacement of service connections, stain on porcelain fixtures and the like. The original galvanized service and house piping had very short life, and yellow brass piping was not a great deal better. Lead, red brass, copper, and wrought iron have been most effective and are the only materials now permitted. Scale and tuberculation have appeared in varying degrees.

A paper presented on June 4, 1940, at the New York Section Meeting, Ithaca, by Allan H. Rogers, Superintendent of Public Works, Garden City, N. Y.

Consideration of sodium silicate and caustic soda led to their elimination as possibilities fairly early in the study of the subject. Treatment with lime was practically decided upon but action was deferred principally because of operating problems. Convenience would dictate lime feed at the pumping station, but much heavier dosing would have been necessary, due to the intervening aeration; and possibly an undesirable increase in hardness would have resulted. There was no point common to all wells where existing plant facilities could be used. From a chemical standpoint, lime feed at the storage tank would have been most desirable, but this would have involved a new building, trucking chemicals, increased personnel, and full automatic control through continuous pH determinations, due to extremely varying flows leaving the storage tank.

The possibility of using sodium hexametaphosphate* was first considered late in 1939. Installation of the necessary equipment was extremely simple. The equipment consists of an "Omega" 50-gallon mixing tank with agitator, feeding by gravity to another 50-gallon solution tank and proportioning pump, which delivers the solution (10 lb. of metaphosphate to 50 gal. of water) from the pumping station through about 800 ft. of $\frac{3}{4}$-inch copper tubing, against 80 lb. pressure, to a point, in the feed main to the storage tank, beyond all well connections, so that water from any one or combination of wells may be treated.

Due to delay in obtaining some of the equipment, treatment was not started until April 9, 1940, but since that date 2 p.p.m. of metaphosphate has been applied, with pumpage averaging about 1,200,000 gallons per day. So that comparative analyses would be as accurate as possible, only one well has been used.

Chemical analyses were made, by the Division of Laboratories and Research of the State Department of Health, on samples collected directly at the well and at the most remote part of the system not on a dead-end main, on March 27, 1940 (prior to treatment), and on April 27 and May 22, 1940. Results are shown in Table 1.

Due to the presence of iron in the water delivered by this well, it is very difficult to form an opinion as to whether the small concentration of iron, in the samples collected from the system, is from this source or whether it represents moderate residual corrosion of the distribution system. Inasmuch as the iron content in the system was the same (0.2 p.p.m.) seven weeks after treatment was started

* Hereinafter referred to as metaphosphate. The metaphosphate referred to in this paper is the commercial product known as "Calgon."

as it was prior to treatment, and hardness, alkalinity and pH value also were identical, it would seem proper to conclude that either the results of the analyses to date do not furnish a sufficiently accurate measure of any beneficial effects of the metaphosphate treatment or that this treatment is not effective with the particular water concerned.

At about the time of starting the metaphosphate treatment, all hydrants at dead ends and points of poor circulation were thoroughly flushed and color conditions were noted. Recently a majority of these same hydrants were again flushed. Fifteen locations showed no change, eleven locations showed color changes of varying degree, and eight locations showed clear water. It was the inspector's opinion that on the most recent flushing, clear water was noted after a relatively short flushing time.

TABLE 1

Results of Chemical Analyses

	MARCH 27TH		APRIL 27TH		MAY 22ND	
	Well	System	Well	System	Well	System
Iron, *p.p.m.*	0.1	0.2	0.07	0.17	0.03	0.2
Total Hardness, *p.p.m.*	10.0	10.0	16.00	14.00	14.00	10.0
Alkalinity, *p.p.m.*	4.0	6.0	6.00	8.00	4.00	6.0
Carbon Dioxide, *p.p.m.*	26.0	7.0	25.00	17.00	26.00	14.0
pH	5.4	5.9	5.50	5.90	5.30	5.9

Results were not expected overnight. It is only reasonable that some time must elapse before the metaphosphate can coat all the metallic surfaces, which comprise the water system, with the molecular film that theoretically provides protection against corrosion. If the rust, scale, and other deposits that have accumulated in the system for many years are to be removed by the so-called threshold treatment of 2 p.p.m., the effect must necessarily be extremely gradual. It is planned to continue the present application of metaphosphate for a reasonable period, particularly into the summer months where greatly increased demand, due to the sprinkling load, may serve to build up a concentration in the system and possibly accelerate the results. Also, it is planned, then, to feed with the metaphosphate through the same equipment, some alkali such as caustic soda or soda ash, to determine if the metaphosphate treatment would be more beneficial with some increase in pH and possibly with some further reduction in free carbon dioxide content.

Bacterial Depreciation of Water Quality in Distribution Systems

By Norman J. Howard

IT WAS originally intended that this paper should cover a much wider field than has actually been attempted. Modification of the original intention is due to a desire not to reiterate much of what has already been covered, but to secure first hand discussion on some essential factors said to be associated with bacterial depreciation of water quality in distribution systems.

The chief questions involved would seem to include the consideration being given to sources of supply, processes involved in purification, and the seasonal incidence and sanitary significance of bacterial deterioration.

What the causes of bacterial depreciation in the distribution system are can, obviously, not be given. Numerous hypotheses have been advanced which, while being plausible, would seem to need further investigation before being generally accepted. One condition frequently observed is that there is a greater tendency for deterioration to occur during the warm summer months when the bacterial pollution of the water is greatest, and when the temperature ranges between 50° and 80°F. For a considerable time past, sanitarians have reported upon types of bacteria which appeared to resist purification treatment. Several have investigated the action of chlorine on laboratory cultures. Such studies with cultures are of great scientific interest and value, because, if it can be shown that under artificial conditions of growth, such organisms can readily be destroyed by chlorine, it can be assumed that similar types should be destroyed when present in water. It is, however, an accepted fact that cultured strains have far greater power to resist the sterilizing

A paper presented on April 24, 1940, at the Kansas City Convention by Norman J. Howard, Director of Water Purification, Island Filtration Laboratories, Toronto, Ont.

action of chlorine than do similar types of bacteria which may be present in polluted water. Consequently, the results of certain studies along these lines must be accepted with a certain amount of reserve. Last year Levine and his co-workers published some valuable results upon studies completed on several strains which had been isolated from water. It was concluded that, "Their presence, as well as the detection of coli-aerogenes strains in chlorinated water, certainly indicates that dependence upon residual chlorine (0.2 to 0.4 p.p.m.), as now determined by the ortho-tolidine test, is not a reliable index of the probable absence of non-spore-forming members of the intestinal group of bacteria. A detailed and thorough investigation into the meaning and significance of residual chlorine under various conditions encountered in water treatment is warranted." All will agree with Levine's conclusions, but it should be emphasized that out of 196 strains which had been isolated and studied, there was not a single record of disease having been caused by any of these cultures, nor was there any suggestion of such a result. We must not lose sight of the fact that these organisms had given some cause for worry due to their presence in the water supply after treatment. More recently, Freiberg reported that, though absent in warm water periods, serious trouble had occurred when the water temperature ranged between 33° and 35°F. The results as outlined by Freiberg are difficult to explain and must represent unusual conditions. If similar findings had been generally reported, our whole conception of the action of chlorine on coliform bacteria might have to be revised. It is conceivable, as Levine has suggested, that some constituent in water may interfere with the action of chlorine on the bacteria themselves. Generally speaking, the average curves, illustrating seasonal quality of water in distribution systems, do not show a corresponding incidence of water-borne disease.

As far back as 1921, W. Firth Wells reported upon the seasonal variation in bacterial flora. He found the number of coliform bacteria present in human feces increased enormously as the temperature rose, reaching its maximum in the month of August. Wells stated that, "The remarkable degree to which three independent curves are parallel cannot be attributed to mere chance. It must be admitted that the seasonal distribution of B. Coli is related to the similar seasonal variation of B. Coli within the intestine." It can, therefore, be assumed, with a great deal of data to substantiate the claim, that bacterial deterioration does closely follow increased

pollution of the raw water and a gradually rising water temperature. Another condition not infrequently observed, that is, the apparent selective action of bacterial removal by filtration, can also be mentioned. The number of coliform bacteria passing a filter will often be found to be proportionately greater than other types of unidentified organisms. It is not uncommon for an unchlorinated filter effluent to contain from 5 to 10 bacteria per ml. and yet give a positive coliform test in 1 ml. Similarly, in chlorinated water, bacterial counts may be under 5 and occasionally give positive coliform tests in 1 ml. No explanation is offered for this, but it seems probable that it results from the fact that the lactose broth is more sensitive than the solid medium.

Two conditions have been reported in distribution systems: first, high bacterial counts but negative coliform tests; and second, low total counts but positive coliform tests. Both conditions usually occur in warm water periods and may give rise to undue, but justifiable, alarm. The trouble may be due to the breaking down of the lining or coating inside the distribution system under favorable temperature conditions; but the unstable and highly complex organic colloids, of which we know so little, may also play a part, during the summer months.

Aims of Research

In reviewing the subject as a whole, we are primarily interested not only in knowing the cause and in ascertaining if any form of treatment will prevent it, but in satisfying ourselves definitely as to whether or not it is of sanitary significance. As previously stated we do not know the reason, and neither do we know what action takes place within the distribution system with a gradually rising temperature. Three definite causes are suggested. First, routine treatment of the raw water may not have destroyed bacterial life completely; later the attenuated organisms under favorable water temperature conditions may start multiplying in the distribution system. Second, bacterial life may be present in a dormant condition on the sides of the pipes and be released as a result of the rising water temperature. Third, in the absence of sufficient residual chlorine, natural decomposition of dead organisms or organic matter may cause increased bacterial growths in the summer months. Again, in this season, there is probably a greater variation in water pressure than normally occurs in other periods of the year, which

variation results in the stirring up of sedimentary deposits within the system. Reference is not made to accidental pollution of any kind or its ultimate effect on water quality in the distribution system because that has no bearing upon the subject under discussion.

Assuming that one of the conditions mentioned is among the

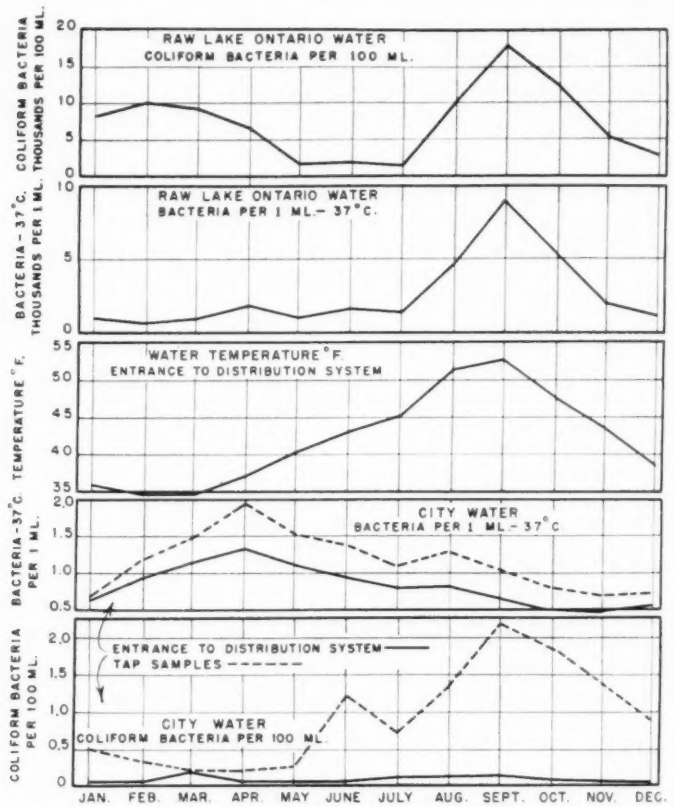

RAW LAKE ONTARIO WATER
COLIFORM BACTERIA PER 100 ML.
COLIFORM BACTERIA THOUSANDS PER 100 ML.
RAW LAKE ONTARIO WATER
BACTERIA PER 1 ML.- 37°C.
BACTERIA - 37°C. THOUSANDS PER 1 ML.
WATER TEMPERATURE °F.
ENTRANCE TO DISTRIBUTION SYSTEM
TEMPERATURE °F.
CITY WATER
BACTERIA PER 1 ML.- 37°C.
BACTERIA-37°C. PER 1 ML.
ENTRANCE TO DISTRIBUTION SYSTEM
TAP SAMPLES
CITY WATER
COLIFORM BACTERIA PER 100 ML.
COLIFORM BACTERIA PER 100 ML.
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.

FIG. 1. Average Monthly Bacteria Counts at Toronto, 1935–1939

direct causes of deterioration, it may be asked if any form of treatment will change the picture and if the bacteria are of any sanitary significance. To the first query, one should, of course, assume that current practice is to treat the water adequately before its entry into the distribution system. In heavily polluted surface water, excessive sterilization treatment may be necessary to prevent after-

growths. If super-chlorination is employed, the destruction of all forms of pathogenic organisms should occur, but secondary decomposition may be more likely to occur unless it is possible to maintain a satisfactory chlorine residual throughout the system. Chloramine treatment following pre- or super-chlorination would seem to be indicated in all heavily polluted waters. In other supplies, where super-chlorination is either impractical or unnecessary, chloramine treatment should theoretically be successful in preventing bacterial deterioration.

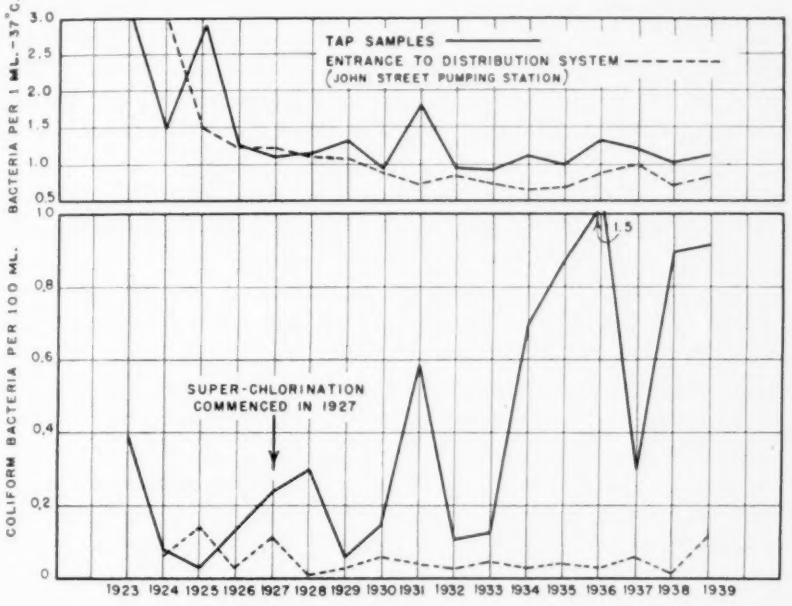


FIG. 2. Average Bacteria Counts in Toronto Distribution System, by years, 1923–1939

In view of the statement made earlier in this paper, that there is no seasonal indication of gastro-enteritis during the troublesome period involved in many cities, it can be stated with a definite degree of assurance that such growths in the distribution system do not constitute a health hazard and are of little sanitary significance. It is perhaps unfortunate that depreciation usually occurs during periods of greatest bacterial pollution. It is, however, most improbable that pathogenic types of bacteria present in water, once having been subjected to adequate and intensive sterilization treatment, can

later become rejuvenated and so become capable of causing water-borne disease. Typhoid fever and gastro-enteritis can alone be caused by an infective agent in active form, and there is no case on record to substantiate any hypothesis that water of satisfactory bacterial quality entering a distribution system can later cause disease as a result of some secondary natural deterioration in quality.

Experience at Toronto

The curves in Figs. 1 and 2 refer to the Toronto water supply, involving super-chlorination treatment, with a normal chlorine residual in the distribution system of approximately 0.075 parts per million. They are particularly instructive, showing the quality of the raw water, the quality of the water entering the distribution system and the seasonal variation in quality of the same water at varying points in the system. It will be observed that the water entering the distribution system is of uniformly satisfactory quality. As this water reaches parts of the system, some deterioration in quality is manifest—such conditions occurring chiefly during the period from July to October. The total bacterial count on standard agar at 37°C. shows little or no change at any period. This same condition is commonly reported elsewhere. In some instances large increases in the total count have, however, been reported.

For many years past, in Toronto, all coliform tests on water in the distribution system have been made upon 100 ml. amounts. The practice of examining finished water in this quantity is strongly recommended, although one must face the fact that if changes are later made in the standards of quality, based upon the examination of water in 100 ml. portions, there may be many large cities which would be unable to meet the required standards.

In conclusion, the writer desires to state that it is his opinion that, if adequate sterilization treatment is employed, no danger exists of water-borne disease, even though some bacterial deterioration may later occur in the distribution system. This opinion is, of course, subject to the assumption that the water entering the system is satisfactory, and that no secondary contamination occurs. Where open reservoirs are part of the distribution system and there is evidence of contamination by bird or fish life or other recognized forms of pollution, preventive treatment should be employed, particularly during the summer months.

Water Treatment and Laboratory Control

A Committee Report

THE nature of the work of the Coordinating Committee on Methods of Water Treatment and Laboratory Control does not permit the formulation of a complete and final report. During the past year the committee has devoted itself to the following activities:

(1) The study of current developments in water purification and laboratory control.

(2) The development of research with the object of securing representative papers for presentation before the Water Purification Division.

(3) Continuation of the investigation of water-borne disease with particular reference to gastro-enteritis.

The activities of this committee are limited to matters related to hygienic quality and the following specific subjects have been assigned to the individual members for study and report:

(1) Relation of water supply to outbreaks of gastro-enteritis.

(2) Resistance of bacteria to chlorination.

(3) Standards of water quality.

(4) Experimental studies of water purification.

(5) Distribution system sanitation.

This year the committee has again sent out questionnaires to all state and provincial sanitary engineers, requesting information on the occurrence of water-borne intestinal diseases. Replies were received from representatives of 36 state and 6 provincial departments of health. These data have been summarized in Table 1. It will be noted that of a total of 279 outbreaks of intestinal diseases which occurred in these states and provinces, only 44 were definitely water-borne, and only 55 suspected to be water-borne. Only 7 of the 44

A report of the Coordinating Committee on Methods of Water Treatment and Laboratory Control presented on April 22, 1940, at the Kansas City Convention by Charles R. Cox in the absence of the chairman.

definitely water-borne outbreaks were transmitted by public water supplies, whereas 18 of the 55 outbreaks suspected to be water-borne involved public water supplies. In general, therefore, *public* water supplies were not of major importance as vectors of disease.

The majority of the outbreaks (168) were classified as gastro-enteritis, and of these only 39 were definitely water-borne, and 24 suspected of being water-borne. Four of the former and 11 of the latter involved public water supplies. Gastro-enteritis and non-specific diarrhea are not reportable diseases, so the data are acknowledged to be incomplete. This is supported by the fact that 60 of

TABLE 1

*Outbreaks of Intestinal Diseases in 36 States and 6 Canadian Provinces during 1939**

DISEASE	DEFINITELY WATER-BORNE		SUSPECTED TO BE WATER-BORNE		MILK-BORNE	FOOD-BORNE	DIRECT CONTACT	UNKNOWN MODE OF TRANSMISSION	TOTAL
	Total	Public Water Supplies	Total	Public Water Supplies					
Gastro-Enteritis	39	4	24	11	9	18	2	76	168
Food Poisoning						15†			15
Bacillary Dysentery	2	1			2		6	6	16
Amoebic Dysentery							1	3	4
Paratyphoid Fever			2	1		1		2	5
Typhoid Fever	3	2	29	6	1	3	12	23	71
Total	44	7	55	18	12	37	21	110	279

* Data furnished by State and Provincial Departments of Health.

† These outbreaks were all in one state. Food poisoning frequently is listed as food-borne gastro-enteritis.

the total of 168 outbreaks of gastro-enteritis occurred in one state where an intensive sanitation program is disclosing a much greater incidence than otherwise would be brought to the attention of state health officials through the usual channels.

Two water-borne gastro-enteritis outbreaks were held to be due to suspected pathogenic bacteria, which, however, were not identified as being members of the dysentery group. Unfortunately, early investigation supported by extensive examination of stool specimens were not possible in most cases, but the indications are that many outbreaks of gastro-enteritis were in reality mild dysentery, although

complete data were lacking. Obviously those outbreaks where pathogens were found were later reclassified as dysentery, typhoid fever, etc.

The data also are indefinite as to bacterial pollution of water supplies implicated in 39 outbreaks held to be water-borne. Twenty-seven of this group were connected with supplies known to contain coliform organisms. Ten instances were cited, however, where outbreaks, which were held to be water-borne because of epidemiological evidence, were in municipalities served by water supplies *not* containing coliform organisms at the time, *insofar as the records indicated*. Supporting evidence is not available to the committee as to these ten instances. It is very significant, however, that several extensive outbreaks of gastro-enteritis occurred during the winter of 1939–40 in one state, among widely scattered populations, where the only apparent common vectors were public water supplies. These supplies were considered to be of safe sanitary quality, but, nevertheless, the outbreaks were held to be water-borne at first because of their widespread character, but later it was found that they were respiratory infections where diarrhea was merely one of the symptoms. Such infections frequently are known popularly as "intestinal influenza." The important point is that epidemiological conclusions based upon less complete data would have implicated these supplies, even though they were free from known bacterial pollution as shown by the absence of coliform organisms. This, of course, would have created confusion as to the reliability of present bacterial standards of quality.

Validity of Previous Conclusions

No evidence has been discovered by the committee that chlorine-resistant, spore-forming organisms are significant or that gastro-enteritis may be due at times to virus infections, although precise information is needed. Such causative agents in water would not necessarily be accompanied by coliform organisms, and thus their presence would not be indicated by current bacteriological procedures.

Current literature contains important but inconclusive data as to outbreaks of water-borne diseases where coliform organisms apparently were absent from the implicated supply, which at the time was so treated as to contain appreciable concentrations of residual chlorine. This literature has been reviewed by the committee since it

was organized following the panel discussion on gastro-enteritis at the Buffalo Convention of the Association in 1937 (Jour. A. W. W. A. **29:** 1137 (1937)). Considered conclusions have been expressed by the committee in previous reports and in the review of the printed reports upon the typhoid fever epidemic at Minneapolis and the gastro-enteritis outbreak at Milwaukee (Jour. A. W. W. A. **31:** 374 (1939)). Finally, the committee took an active part in another panel discussion at the 1939 convention (Jour. A. W. W. A. **31:** 1475 (1939)). At the present time the committee finds no specific data which justify a change in the general conclusions expressed heretofore.

Research Project

The City of Detroit, through the activity of a member of this committee, Wallace, is to make an exhaustive study of the bacterial flora of the *treated* water in its distribution system, to ascertain whether organisms likely to be pathogenic can be isolated. This study is based upon the fact that though the water pumped into the system meets accepted standards of quality, many mild cases of gastro-intestinal disorders occur in the city, especially in the spring and fall. The water supply, of course, may not be involved.

This committee wishes to encourage such investigations, whereby more intimate knowledge as to the bacterial quality of a specific supply may be correlated with prevailing treatment and the incidence of diarrheal diseases. It seems pertinent, however, to stress that the examination of numerous stool specimens during an outbreak, coupled with the serological proof that the isolated pathogens or possible pathogens were actually responsible, constitutes the best procedure for determining the cause of water-borne gastro-enteritis. Other approaches are likely to lead to the isolation from samples of treated water of organisms similar to known pathogens but where their pathogenicity cannot be determined in the absence of stool specimens and sera from patients recovering from an outbreak in which the supply was implicated. Any study of bacterial quality, therefore, must be closely associated with the medical aspects of the problem before definite conclusions can be reached that known pathogens pass through filters, and resist conventional chlorination.

It is believed rather that more stress should be placed upon both endemic and epidemic diarrhea which may be transmitted by numerous channels such as by direct contact or by vectors such as food, milk

and secondary water supplies, or which may be symptomatic of the respiratory disorder previously mentioned as being popularly known as "intestinal influenza." These important vectors should be more carefully investigated before a water supply is implicated merely because it appears to be the only common factor to a widespread group of cases of gastro-enteritis.

Pending the collection of conclusive evidence, a cautious attitude is needed, but at the same time confidence is justified in present water purification procedures, *provided these procedures are properly applied and controlled, and provided the desirable factor of safety is available.*

It would seem that little can be gained by further statistical study of this subject by this committee pending the development by health departments of more precise statistics as to the incidence of water-borne gastro-enteritis, and as to the causative agents of such disorders. It is proposed, therefore, to devote attention in the future to the problem of maintaining water of safe sanitary quality in distribution systems, and to the chlorine resistance of bacteria of sanitary significance.

(The committee lost one member, Professor Leon B. Reynolds, by resignation, during the year.)

Personnel of the Committee
GEORGE D. NORCOM, *Chairman*
L. F. WARRICK
WM. WALLACE
CHAS. R. COX
MAX LEVINE

The Water Quality Requirements of the Soft Drink Industry

By Kennon Mott

THE "carbonated beverage" or so-called "soft drink" industry is subject to some definition. It includes sales of beverages at soda fountains as well as bottled beverages. It includes the making of flavor beverages with both carbonated and "plain" (non-carbonated) water. It also includes the making of flavor beverages with milk products.

In considering the industry, the draft or soda fountain end of the industry is generally designated the "soda fountain division," as differentiated from the "bottled beverage division."

The use of sweetened waters has been practiced for many years but the modern soft drink industry covers a comparatively short span. This is particularly true of the bottled beverage division, which is a product of the twentieth century.

The growth, however, has been most rapid, and the present size and general importance of the industry is impressive. It is truly a billion-dollar industry, the annual gross sales far surpassing that figure. In fact, the annual gross sales of the soda fountain division, alone, exceed a billion dollars a year, and the latest figures on the bottled beverage division place it in a similar class. Translating such money figures into individual drinks staggers the imagination.

As over 80 per cent of carbonated beverages is water, the tremendous importance that water plays in the maintenance and further development of the industry is obvious.

In the early stages of development, and even up to the last few years, the real significance of a proper water supply was apparently not recognized. As the industry has grown in size and importance,

A paper presented on April 25, 1940, at the Kansas City Convention by Kennon Mott, Manager, Bottler's Service Department, Nehi Corporation, Columbus, Ga.

however, it is only natural that closer study has been given to all items that would in any way affect the product. This study, of necessity, included consideration of the condition of the water supply.

In the past it was considered that if a water was free of pathogenic organisms and visible sediment it was satisfactory to use for beverages. Such an opinion still exists today among many interested individuals, both directly within the industry and also on its outskirts. One of the major reasons for such an attitude was and still is the lack of guiding information.

Due to the efficient activities of the technical department of the American Bottlers of Carbonated Beverages, generally, and more specifically due to the activities of manufacturers of products, nationally produced and distributed under franchises, considerably greater knowledge of necessary water standards has been gained.

The quality requirements of the industry touch on many properties of the water, and to each may be given a specific definition, as follows:

(1) Good sanitary quality means water which at all times meets the bacteriological standard established for interstate common carriers by the United States Treasury Department.

(2) Clear and sparkling water would be that of low turbidity and which would favorably compare to distilled water on visual observation.

(3) Colorless would mean a water without visible color and which would compare favorably in color upon visual comparison with distilled water.

(4) Lack of odor in a water means absence of all observable odor of any nature when submitted to both cold and hot test.

(5) Freedom from suspended matter means a water which contains no sediment in suspension which is visible to the naked eye. It also, however, calls for freedom from very minute particles of insoluble substances, such as silt, mud, small plants and animal forms or other debris which are only observable under a microscope.

(6) A definite standard designating an unobjectionable degree of total hardness appears not to have been generally enunciated. It has been considered, by some of those who have given careful and serious consideration to the matter as pertaining to beverages, that total hardness of 200 parts per million or less could be considered unobjectionable, and over that figure objectionable.

(7) Again there is a variance in opinion as to the exact standard for degree of total alkalinity, but again, those who have given careful

thought and study to the matter state that total alkalinity of less than 50 p.p.m. could be considered unobjectionable, and of more than that figure objectionable. It is, however, considered that the lower the degree of total alkalinity, the better.

(8) An iron content of less than 0.1 p.p.m. would be considered unobjectionable.

These standards are based on what experience has dictated to be the requirements of and for the industry. Beverages are, in reality, a food product, and, as such, must be manufactured and sold on the same bases as other products for human consumption. It is essential that they be free from pathogenic organisms of any nature, and that they contain no matter detrimental to health. Also, complete sanitation is necessary to the protection of flavor. Clarity and color of the water also affect the salability of the product from the point of view of its sparkle and general appearance. Tasteless and odorless water is, of course, necessary to protect the taste and bouquet of the beverage as they are its primary reason for existence.

It has been determined that some beverages are affected by the use of water of objectionable hardness; but there does not exist, at the present time, authentic, scientifically controlled experience or data to warrant an opinion as to the actual effect of varying degrees of permanent hardness of water on the flavor or taste of different beverages. The hardness of water affects the soft drink industry, however, in regard to the washing of the containers used in serving the beverages. Where equipment is used for washing the containers, it is possible to condition the water being used by use of washing compounds. Such procedure is difficult, however, for properly conditioning the rinse water. Waters containing magnesia leave a film on the rinsed bottle and with continuous washing of the bottle there develops in time what is called a "cloudy bottle," which is unsightly and has to be destroyed. Permanent hardness also gives the manufacturer of bottled beverages trouble in the creation of a scale on the bottle-washing machine parts.

An objectionable degree of alkalinity adversely affects the flavor of beverages by neutralization of the important acid content. The percentage of neutralization varies according to the acid content. Various acids are used in beverages, most generally phosphoric, citric and tartaric. Considerable expense has been involved in determining the exact amount of acid that will give the desired results. Any variance in the established acid content means varying flavor and lowered quality. The acid is also an agent of stabilization. The

elimination of any of the acid content adversely affects the stable qualities of beverages, and shortens their "shelf life." Tartaric acid has been found to form insoluble precipitates in some waters that are high in calcium. Where the water contains acid-neutralizing alkalinity, it might be considered possible for the acid content of the beverages to be varied to off-set such neutralization. Neither is such action practical nor desirable, as the addition of acid in such cases would, due to further chemical reaction, create an objectionable saline taste. Even if the procedure were satisfactory for the individual local manufacturer, it still would not be desirable where nationally distributed franchised beverages were concerned. Objectionable alkalinity and varying degrees of such alkalinity most definitely make the standardization of flavor difficult or practically impossible.

An objectionable dissolved iron content not only might seriously affect the quality of the beverage, due to giving it a more or less noticeable metallic taste, but it would also prove detrimental to a manufacturer, due to its effect on the pipe lines and equipment in causing discoloration, building up deposits and creating a taste and odor problem.

The importance of a standard water supply, that is a water conforming to listed standards, is fully recognized by a portion of the bottled beverage division of the soft drink industry, but whether it is recognized or not, the importance is still real. A real problem confronts the industry in securing such a standard. Because of the variance in the chemical and physical characteristics of different waters, due both to origin and to the treatment or lack of treatment by water suppliers, the problem of water treatment for a given plant has to be considered as an individual problem. It is recognized that even though a water supply at its source, for instance, at the outlet of a municipal water plant, is shown to be standard, still it may not be free from suspended matter at the manufacturing plant, due to pick-up of such substances as iron and various growths from the walls of the pipes as it passes through the distribution system.

Variance in forms of analyses made by different laboratories and lack of standard interpretation of such analyses present a distinct problem. Bacteriological examinations are, at best, difficult to make, and health departments are depended upon to that end. Other laboratories, however, often confine themselves to the physical and chemical examination without giving due importance to the microscopical examination. Even though a satisfactory analysis is made,

the interpretation is sometimes faulty due to lack of understanding of necessary standards, to over-zealousness or bias on the part of the interpreter in favor of his water supply, equipment or opinion, or due to lack of sufficient knowledge to apply practically the information offered by the analysis.

The initial cost, operating cost, and space occupied by duplicating a water plant on a small scale for industrial use present an almost insurmountable barrier to some members of the industry, and even though the necessary equipment be secured in a percentage of cases, the non-technical training of the industrialist and his employees makes control of the equipment most difficult and, at times, the effluent water from such conditioning equipment is not as good as the raw water entering.

The unfortunately slow process of educating humans to a realization of doing things which will prove of value to them presents a problem that is difficult to overcome in any reasonable length of time. It is of interest to note that, even with the active and aggressive attention being given to the problem of proper water conditioning, over a period of two years, only approximately 50 per cent of one important manufacturer's outlets have been fully impressed with the necessity of fully, and not just partially, conditioning their water supplies.

The foregoing might indicate the necessity for and distinct value of cooperation on the part of water suppliers. Such cooperation, as would make merely basic water conditioning equipment necessary at the point of usage would be of utmost value. By "basic water conditioning equipment" is meant filtration equipment, and equipment for protection against and elimination of objectionable tastes and odors

It is sincerely felt that water suppliers recognize a responsibility to industry generally in line with their recognition of their responsibility to the general public to supply good drinking water. It is also felt, however, that they could well feel a responsibility specifically to the soft drink industry, and through it to the consuming public. In fulfilling such a responsibility, other industries would be benefited, for a casual observation of their water requirements shows that industries, such as textile, laundry, ice-making and swimming pool, require, in part or entirely, water supplies with standards comparable to those of the soft drink industry.

Calcium Hypochlorite in Water Purification

By John O. Logan and Walter L. Savell

IN APRIL, 1918, Joseph Race in the preface of a book he wrote and published that year (1), said: "No apology is necessary for the publication of a book on the chlorination of water. This method of treatment, practically unknown fifteen years ago, has advanced in popularity during the last decade in a most remarkable manner, and in 1918, over forty millions of people are being supplied by chlorinated water."

There is more than a hint in that statement of the popular prejudice which still existed against chemical treatment of water in general and against chlorination in particular.

That the prejudice was not entirely dispelled at the time is shown, too, in a statement by Samuel and Eric Rideal (2) in 1921, to the effect that "chemical sterilization is mainly to be regarded as an emergency method. The cheapest chemical, apart from the labor and trouble involved, must necessarily render the operations costly. Under special circumstances, however, this method may become useful and even necessary."

As early as 1908, the water from Bubbly Creek, then used to supply the Union Stock Yards, had been chlorinated. This was brought about by G. A. Johnson as a result of complaint by the City of Chicago, citing the deleterious effect of the water from the Bubbly Creek filter plant upon the animals consuming it.

At about the same time, Johnson and Leal started chlorination of the Boonton supply of Jersey City, N. J. The water consumption of that city was then approximately forty million gallons per day.

A paper presented on April 25, 1940, at the Kansas City Convention by John O. Logan, Technical Representative, Mathieson Alkali Works, Inc., Chicago, and Walter L. Savell, Manager, Technical Division, Mathieson Alkali Works, Inc., New York.

Boonton Case

The problem of popular prejudice against chemical treatment of municipal water supplies was one of major importance, and the Boonton case proved to be the one upon which further progress in water purification depended in no small degree. The chlorination treatment was attacked and made subject of a lawsuit. While it is certain that chlorination would have been established eventually, both technically and in the good graces of water consumers, the court decision in this case gave a much needed impetus. The court decision reads as follows:

"From the proofs taken before me, of constant observation of the effect of this device, I am of the opinion and find that it is an effective process which destroys in the water the germs, the presence of which is deemed to indicate danger, including the pathogenic germs so that the water after this treatment attains a purity much beyond that attained in water supplies of other municipalities. The reduction and practical elimination of such germs from the water was shown to be practically continuous.

"Upon the proofs before me, I find that the solution described leaves no deleterious substances in the water. It does produce a slight increase in hardness but the increase is so slight as in my judgment to be negligible.

"I do therefore find and report that this device is capable of rendering the water delivered to Jersey City pure and wholesome, for the purposes for which it is intended and is effective in removing from the water those dangerous germs which were deemed by the decree to possibly exist therein at certain times (3)."

It is good, occasionally, to look back to the past, not only to recognize the valiant work of the pioneers, but also because it enables us to gage more accurately just how far we have come since those early workers opened the doors.

All of this early work has a definite and direct bearing on the subject, since treatment of the Boonton supply of Jersey City, and, in fact, of all of the earlier chlorinated supplies was carried out with solutions of calcium hypochlorite.

The desirability and necessity of effective and economical methods of water purification had been recognized long before the technical nature of the problems involved had been developed. Progress was comparatively rapid, however, after Pasteur, in 1863, established

the relation existing between micro-organisms and disease. Investigations ranged far and wide in a search for methods and materials for suitable water purification.

Early Purification Materials

Records of results of experimental treatment of water in efforts to accomplish practical disinfection include the use of:

Ozone	Chlorine Peroxide
Hydrogen Peroxide	Sodium Silicofluoride
Sodium Peroxide	Aluminum Silicofluoride
Calcium Peroxide	Silver Chloride
Magnesium Peroxide	Silver Fluoride
Lime	Colloidal Silver
Iodine	Colloidal Copper
Bromine	Various Copper Salts
Chlorine	Iron Salts
Fluorine	Almost All Common Acids
Chloramines	A Wide Range of Alkalies

From this welter of materials, by a process of elimination and over a period of time, calcium hypochlorite and chlorine stand out as the most effective and most generally practical of all the available disinfecting reagents for use in the modern water purification plant and distribution system. First one and then the other of these two chemicals has taken the spotlight.

Alternate Popularity of Chlorine and Chloride of Lime

It is interesting to note the cycle through which chlorine and calcium hypochlorite, as disinfectants, have passed since chlorine was first discovered by Scheele in 1774.

First, used as a disinfectant in the form of gas in 1800, by Morveau in France and by Cruikshank in England, chlorine was prepared by heating a mixture of hydrochloric acid and manganese dioxide (pyrolusite) (4). The difficulties of handling such a mixture are obvious and require no comment. It is, therefore, easy to understand that the hypochlorites which later become available in solution, and chloride of lime, from which hypochlorite solutions could be prepared, would and did receive a hearty welcome from those who were looking to chemistry as a means of helping to solve the problems of sanitation.

During the nineteenth century the use of chloride of lime gained great impetus in the field of sanitation, finally achieving acceptance and public respect after the favorable decision in the Jersey City test case previously discussed.

At about this time (1909) chlorine gas again came on the scene, this time in the form of a liquid under pressure in cylinders. By 1913, the battle between chloride of lime and liquefied chlorine gas in cylinders was well under way. One author said "It is quite possible that there may be instances where the use of liquid chlorine may have its advantages over that of chloride of lime, but even then, the cost of liquid chlorine will be considerably higher" (5).

Naturally, the usual reluctance to change was met on every hand, but chloride of lime eventually had to give way to the newer and more dependable liquefied chlorine gas.

Although chloride of lime represented a vast improvement, as a carrier of available chlorine, over the cumbersome methods of chlorine gas generation first proposed, it still was far from being an ideal reagent to use. It had several very serious faults, including a strong chlorinous odor and decidedly corrosive nature, but its greatest failing was the lack of stability. Even before it reached the height of its popularity in water treatment, the unstable nature of chloride of lime was well known, not alone to the manufacturers, but to chemists and operators who used it.

Freshly prepared chloride of lime carried from 35 to 37 per cent available chlorine. The user, however, could not depend upon its strength from one day to the next. Adverse conditions, such as warm weather, might account for a loss of available chlorine from 37 to 20 per cent in a few days; and in some extreme cases the decomposition in storage was complete within a period of a few weeks so that the user had no available chlorine in his drums when he came to use them.

A natural result of the faults of chloride of lime and the advent of more dependable reagents has been the practically complete elimination of this product from the field of water purification.

As we all know, liquid chlorine is now doing the major job of water disinfection throughout the country, and in most other parts of the world. To paraphrase the quotation just cited, however, we do find that there are "numerous instances where calcium hypochlorite has definite advantages over liquid chlorine, even though the cost per pound of available chlorine may be higher in this form."

Modern Calcium Hypochlorite

It was the recognition of the advantages that chloride of lime offered, as well as the disadvantages of properties and use, that led to the long years of research and the development of its logical successor—the modern, stable, highly soluble calcium hypochlorite.

Whereas chloride of lime was of variable composition and extremely unstable, the modern true calcium hypochlorite is of constant composition, is extremely dependable in stability and carries twice as much available chlorine. In this connection, it is interesting to note that a drum of calcium hypochlorite carries more available chlorine per unit of weight than that carried in a cylinder of chlorine.

Thus chlorination for disinfection has been seen to start with chlorine gas, change to chlorination with calcium hypochlorite solutions made from chloride of lime, then change back to chlorine gas supplied as a liquid under pressure, and finally turn again to calcium hypochlorite used generally in solution and prepared from true dry calcium hypochlorite.

To be sure, the progressive development of chlorinating agents has been more than a simple cycle, since no step has ever completely eclipsed the previous ones. The cycle has, therefore, taken the form of an ascending spiral. Direct generation of chlorine by chemical means is no longer practiced for practical disinfection. Chloride of lime has become a definitely secondary item in production and in all the former fields of application. Liquid chlorine holds the position of chief disinfectant to large water supplies, most ably seconded by the assistant chief disinfectant, dry calcium hypochlorite.

The properties of stability and high available chlorine content make calcium hypochlorite ideal for many uses in water purification systems. In fact, it is in use for all chlorination purposes, including: complete and emergency chlorination of water supplies; chlorination of new distribution lines; disinfection of filters; disinfection after cleaning reservoirs, pipe lines and all accessory equipment in water purification plants; chlorination of deep wells and fittings after drilling and before putting the well in service; all general disinfection around the water plant.

In this discussion frequent reference has been made to chloride of lime, variously known as bleach and bleaching powder. In the past it has been erroneously called calcium hypochlorite. It is true that solutions of calcium hypochlorite are formed when chloride of

lime is dissolved in water, but these occur only with the hydrolysis and splitting of the complex molecule of the oxychloride. This point is emphasized to eradicate any remaining opinions that modern calcium hypochlorite is in any sense an improved chloride of lime. The two compounds are related only as sources of available chlorine. They differ completely in methods of production and properties. The methods of production are of interest chiefly to the producer; the properties of the modern calcium hypochlorite are important to the producer and consumer or prospective consumer alike.

Properties

In giving consideration to the possible use of modern calcium hypochlorite, a number of questions naturally arise in the mind of the prospective user.

Of primary interest, of course, is a description of its properties. Modern calcium hypochlorite is a dry, white, practically dustless granular material weighing approximately 45 pounds per cubic foot. The grain size is such that practically all will pass a 20-mesh screen. It flows readily in the dry form and may be handled easily in the average dry feeder. It shows no tendency to cake under ordinary conditions. If exposed to very humid conditions, however, it tends to form a superficial solution on the grain surface. This will tend to cement the grains together, resulting in lump effects on the exposed surfaces. Since it has the property of absorbing moisture to some degree, it should be stored in a dry atmosphere and kept in covered containers.

The granular product is a recent improvement in calcium hypochlorite. As first produced it was a fine, rather dusty and bulky white powder. The present improved granular product was developed to eliminate the dust and the consequent unpleasantness and discomfort experienced in handling and applying the early material. The granular product also made possible the application of dry calcium hypochlorite in dry feeding machines which could not be used with the powdered product. While the tendency to absorb moisture was never excessive, this tendency has been materially reduced in the granular form. Moisture absorption is largely a function of area of surface exposed, and the fine powder, formerly manufactured, exposed an immensely greater total particle surface area, per unit of weight, than is the case with the granular material.

Available Chlorine Content

Another point of interest is the proportion of available chlorine contained.

The modern calcium hypochlorite contains over 70 per cent available chlorine. This means literally that each pound of dry calcium hypochlorite will do the chlorinating job that would require over 0.70 pounds of chlorine to do. The available chlorine is present in the form of actual calcium hypochlorite of the chemical formula, $Ca(OCl)_2$.

Calcium hypochlorite is in one sense a chemical paradox. In the formula, available chlorine content is just exactly twice the total chlorine content. To get a satisfactory explanation for this we must consider the conditions surrounding the early uses of chlorine and chlorine compounds, and the traditions we have inherited from them.

When chlorine was first applied as a solution of the gas in water, methods were soon developed for estimating the amount or concentration of chlorine in the solution. These methods of analysis all depended upon the oxidizing properties of the chlorine water solution for quantitative measurement of chlorine concentration. The term "available chlorine," as applied to usable chlorine contained in these solutions was quite logical. The same method of analysis could have been applied, however, to a wide range of oxidizing compounds even though they have no chlorine content whatever, and the results reported in terms of available chlorine.

When chloride of lime and hypochlorite solutions were produced, the traditional method of evaluating them in terms of available chlorine continued. This was partly justified by the fact that the available chlorine content of these various compounds could be generated as chlorine gas by acidifying them with hydrochloric acid. The technical error in such reasoning is apparent from the fact that manganese dioxide will generate chlorine gas if treated with hydrochloric acid and, therefore, could be said to contain available chlorine according to the traditional basis of evaluation.

Since calcium hypochlorite is a chlorine compound and has received its oxidizing value from chlorine, there is a shade more reason for measuring its oxidizing power in terms of chlorine than there would be for using the available chlorine basis for evaluating the oxidizing power of hydrogen peroxide, for instance.

Nevertheless, in determining the active value of calcium hypo-

chlorite and other chlorine compounds carrying "available chlorine," we are actually measuring the oxidizing value of these compounds in terms of the proportional weight of chlorine required to give the same oxidizing value. Or to reverse the statement, we are determining the proportional amount of chlorine which had to be applied to give calcium hypochlorite the oxidizing power which it has.

Briefly, then, the term available chlorine is applied to chlorine-containing oxidizing compounds capable of generating free chlorine. The available chlorine content is the oxidizing power of the compounds expressed in terms of the equivalent amount of chlorine.

Such a review of the traditional history of the term available chlorine makes it easier to understand how it is possible to carry such a high content of available chlorine in a dry granular product such as the modern calcium hypochlorite.

Comparing a cylinder of chlorine with a drum of calcium hypochlorite, the interesting fact is revealed that a chlorine cylinder carrying 150 lb. of liquid chlorine will have a gross weight of 250–260 lb. Thus the liquid chlorine represents only about 40 per cent of the gross weight. A 100-pound drum of calcium hypochlorite will have a gross weight of 114 lb. The available chlorine content will be over 70 lb., or 61 per cent of the gross weight. In other words, a drum of calcium hypochlorite carries over 50 per cent more available chlorine per unit of gross weight than that carried by a cylinder of liquid chlorine.

Oxidation Potential

Another point of considerable interest is the fact that the high content of oxidizing or chlorinating value is accompanied by a high oxidation potential. This, of course, simply means that it is a very reactive oxidizing agent and will oxidize many materials that might be less affected or not oxidized at all by less reactive oxidizing agents such as hydrogen peroxide.

This property of calcium hypochlorite should be given proper consideration by the user. Reaction is spontaneous with many common organic substances such as turpentine, sugar, oils, fats, etc. For this reason any tools, such as scoops, used in handling calcium hypochlorite should be clean and dry. A small fire has been caused by allowing dry calcium hypochlorite to stand in a pail which had been used for carrying turpentine. After a contact period of several minutes, the rate of oxidation of the turpentine by the calcium hypochlorite became sufficiently rapid to cause a temperature increase to

the ignition point of the turpentine. At this temperature the calcium hypochlorite itself decomposes rapidly. Additional heat caused by the decomposition raised the temperature of the pail and its contents to a red glow. At high temperatures, calcium hypochlorites will react violently with sulfur-containing materials, such as molten jointing compounds used in construction of cast-iron pipe lines.

The high oxidation potential indicated by such reactions is the property which is so useful in the water purification process for destroying living organisms.

Recent but extensive experiments have shown that heavy doses of chlorine or calcium hypochlorite in water can raise the oxidation potential of the treatment enough to destroy organic matter responsible for many undesirable tastes and odors, including the chlorophenolic taste. This heavy chlorination, sometimes called breakpoint chlorination, is receiving much expert attention at this time.

Stability

Obviously, any compound that is absolutely stable, under all ordinary conditions, would be useless as a chlorinating or oxidizing agent. We have to choose, then, the compounds which are most stable under conditions required in manufacture, packing and storage, but reactive to the desired degree under normal conditions of use. Necessarily, such a choice is something of a compromise. Calcium hypochlorite represents the ultimate, achieved to the present, in stability in production, packing and storage with a maximum of convenience and chemical activity under conditions of use.

In storage at 86°F. for a period of a year the loss of available chlorine will not be more than 10 per cent of that originally present. At lower storage temperatures this loss is decreased. For all practical purposes, therefore, and under any normal condition of use, the stability may be taken for granted. Compared with compounds previously available, such as chloride of lime, such stability is phenomenal.

Applicability

A final factor in the consideration of calcium hypochlorite must, of course, be its applicability. Modern calcium hypochlorite is good for application in any job of disinfection that can be satisfactorily done by chlorination. This covers substantially any disinfecting job connected with water treating processes, purification plant and distribution system.

While it is highly improbable that calcium hypochlorite will ever be used as the principal chlorinating agent in the general disinfection of large water supplies, it is, in many small communities and in private water supply systems, serving as the sole chlorinating agent.

Slowly, the public is coming to realize that no water supply is safe unless chlorination is used to insure freedom from dangerous pathogenic organisms. Out of this realization has developed a demand for reagents and equipment that can be used in combination to provide practically automatic treatment for small independent water supplies. Calcium hypochlorite is practically ideal as a dependable, convenient chlorinating agent. Ingenious and adequate equipment, capable of feeding hypochlorite solutions and other treating reagents, has been developed by several manufacturers. Small units are available for treating small supplies with any single application such as simple chlorination to any combination of treatments including super-chlorination, or break-point chlorination, treatment for coagulation, filtration, softening, de-chlorination, etc.

In every community the health officers and water works officials, chemists and operators are looked upon, by farmers of the vicinity and others dependent on small private water supplies, as consultants from whom sound advice may be obtained on matters pertaining to disinfection and purification of those small supplies. An emergency stock of calcium hypochlorite, on hand in the municipal plant, may provide a practical and immediate means of solving many a serious and pressing problem of safe-guarding the health of one or more families and at the same time of taking care of the interval which may elapse before regular supplies may be obtained for treatment in the private water system.

In the treating plants handling large volumes of water, calcium hypochlorite is often used as a chlorinating standby and safety factor. If the standard chlorinating system fails, for any reason, calcium hypochlorite may be dissolved in water and allowed to drop from a barrel or other container to supply the necessary chlorination. Extra demands for water, such as large municipal fires, may tax installed chlorinating equipment beyond capacity. The standby calcium hypochlorite functions in this case to supplement the regular chlorinating process to insure against under-chlorinated or contaminated water getting into the distribution lines.

Floods are sometimes responsible for excessive pollution of normally good supplies. Extra pollution may very well create *such* an abnor-

mally large chlorine demand that it can only be satisfied by using emergency methods. Here again calcium hypochlorite can step into the breach.

In fact, because of its convenience, high concentration, dependability and flexibility in use, modern calcium hypochlorite will fit simply and quickly into any job of disinfection connected with the water purification system, from algae control in the raw water supply to washing down and disinfecting reservoirs, settling basins, mixing equipment, filters, floors, runways, pipe lines and in fact the whole distribution system.

It must be remembered, of course, that while the subject of this paper has been calcium hypochlorite, the remarks previously made are intended to include the use of this reagent as a source of chlorine in preparation of chloramines for any of the services named. In this connection, it is well to keep in mind the usual precautions in the preparation and use of chloramines. The ammonia should be added to the water first and sufficient run allowed to permit complete mixing with the water. Then the calcium hypochlorite solution should be added. Rapid mixing is essential at this point also to obtain satisfactory chemical efficiency.

It is not intended in this discussion to go into the details covering the application of calcium hypochlorite in the many uses to which it has been put. It is sufficient to say that it has proved its pre-eminent value as a standby and emergency chlorinating reagent; it fits into many special applications in chlorinating and disinfecting, for which no other material serves as well, and it has filled a demand in treatment of small supplies, for which it is the only present logical answer.

References

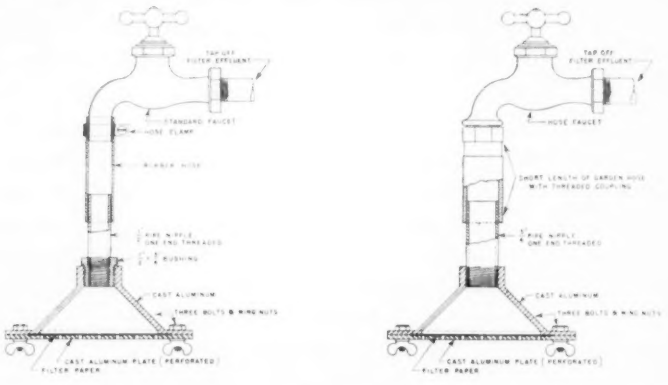
1. RACE, JOSEPH L. *Chlorination of Water.* John Wiley & Sons, New York (1st ed., 1918), preface.
2. RIDEAL, SAMUEL AND ERIC. *Chemical Disinfection and Sterilization.* Edward Arnold & Co., London (1st ed., 1921).
3. American Jour. Pub. Health. **1:** 1566 (1911).
4. RACE, JOSEPH L. *op. cit.*, p. 3.
5. HOOKER, A. H. *Chloride of Lime in Sanitation.* John Wiley & Sons, New York (1st ed., 1930).

Concentrator for Solids in Filter Effluent

By Herman Weigand

READERS of this JOURNAL will remember the article in the January, 1940, issue, entitled "Effectivness of Sand Filters in Removing Floc," by McCall, Edwards and Hopkins.

Some JOURNAL readers may have wished to have a method of obtaining a continuous water sample other than the one outlined in the article.



At Leavenworth, Kan., in the summer of 1939, a device, by which filter performance may be checked and the best method of washing the filters determined, was developed. Attached to a faucet on the filter effluent line, this device enables the operator to collect any material passing through the filters. The material is then examined both chemically and microscopically in the laboratory. As the conditions warrant, the device may be used advantageously for a given period of time—an hour, 24 hours, or the duration of the filter run—or by passing through it a given amount of water—one gallon, 100 gallons, or 1,000 gallons.

A contribution by Herman Weigand, Chief Operator and Chemist, Leavenworth City Water Department, Leavenworth, Kan.

Bacterial Pollution of the Niagara River

Part 2. Improvement in Conditions After Sewage Treatment At Buffalo

By G. E. Symons and R. W. Simpson

IN PART 1 of this report (1), the authors discussed a 25-month study of the conditions and extent of bacterial pollution of the Niagara River before sewage treatment at Buffalo. On July 1, 1938, the Buffalo Sewage Treatment Works was placed in operation. Since that time the Bird Island Laboratory of the Buffalo Sewer Authority has continued monthly surveys to determine the improvement in the conditions of the river following sewage treatment and disinfection. This paper summarizes and presents the findings of 23 months of additional studies.

The details of the methods of study were the same as reported in Part 1. A brief review of these details, with exceptions, will suffice at this point. Bacterial data are reported per milliliter and as quantity units (2) based on the flow in the sections of the river represented by the sample. All samples were collected in a depth sampler. When samples were collected by boat, the coliform inoculations were made within a short time thereafter. Serial dilution (3 tubes) in lactose broth (partial confirmation) was used for the determination of the most probable numbers (M.P.N.) of coliform bacteria.

The 1936 surveys showed relatively no pollution in Lake Erie or in the Canadian channel around Grand Island. All sampling was, therefore, confined to the American channel.

Figure 1 shows the location of the sampling stations and Table 1 lists the series of stations, the distance of each from the beginning

A paper presented on June 6, 1940, at the New York Section Meeting, Ithaca, by G. E. Symons, Chief Chemist, and R. W. Simpson, Associate Sanitary Chemist, both of the Buffalo Sewer Authority. Part 1 of this study, published in the July, 1939, JOURNAL, discussed conditions before sewage treatment at Buffalo was started.

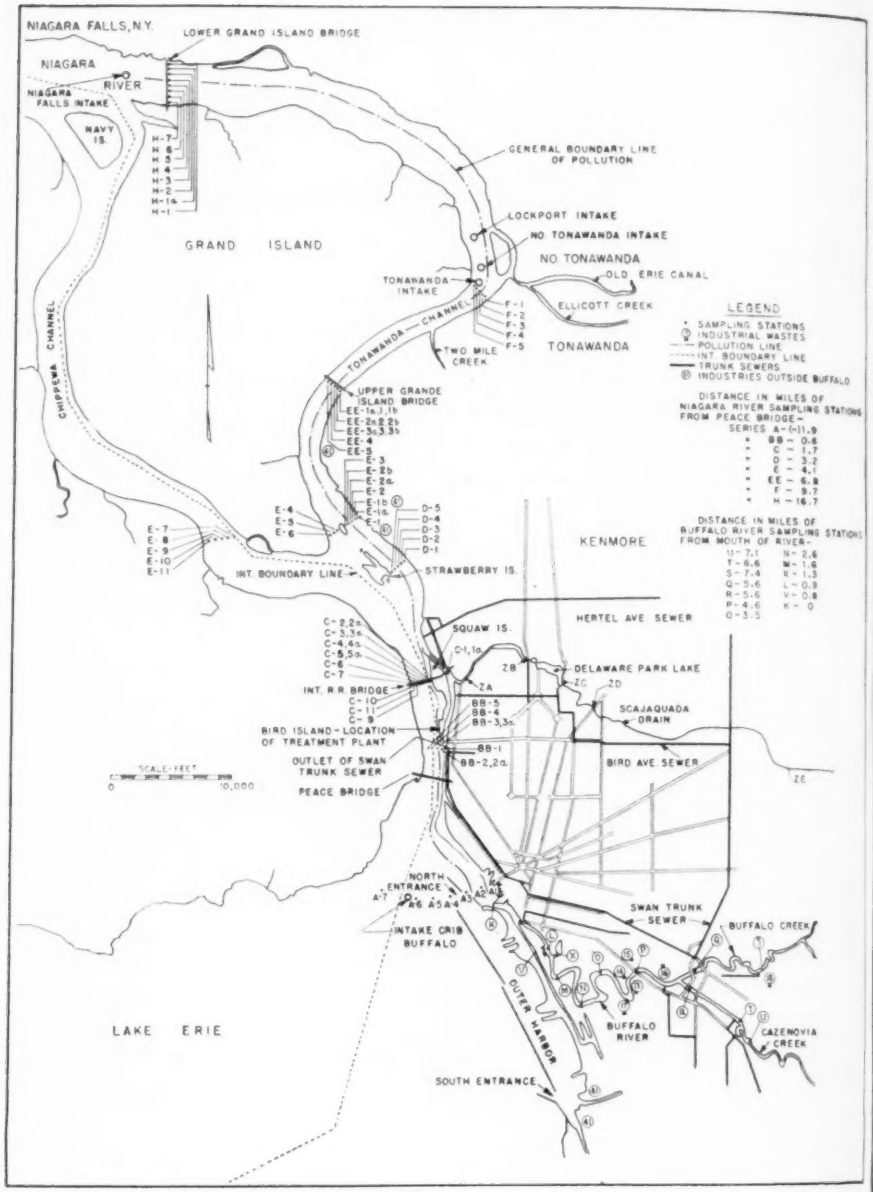


FIG. 1. Location of Sampling Stations

of the river (Peace Bridge) and the flow time for a flow of 185,000 cu.ft. per sec. The outfall of the sewage treatment plant is about 0.4 miles below Series BB.

Sewage pollution formerly entered the Niagara River at many points. These included large sewers discharging directly into the river and the discharge from the septic Buffalo River and Black Rock Canal. Interception of the sewage for treatment removed much of the pollution from both the Buffalo River and the Canal. Comparative studies (3) on the Buffalo River and Canal before and after sewage treatment show that the Canal is now free from pollution and the Buffalo River has been improved by 80 per cent insofar as bacterial pollution is concerned and 50 per cent on the basis of biochemical oxygen demand (B.O.D.). It is also to be noted that

TABLE 1

Location of Sampling Stations in Niagara River Surveys

SERIES	LOCATION	DISTANCE BELOW PEACE BRIDGE	FLOW TIME FROM PEACE BRIDGE
BB	Ferry Dock	0.6 mi.	0 hr. 10 min.
—	Outfall of Sewage Treatment Plant	1.0 "	0 " 15 "
C	International R. R. Bridge	1.7 "	0 " 25 "
D	Strawberry Island	3.2 "	1 " 25 "
E	Motor Island	4.1 "	1 " 45 "
EE	Upper Grand Island Bridge	6.8 "	3 " 45 "
H	Lower Grand Island Bridge	16.7 "	11 " 40 "

industrial waste removal from the Buffalo River is still in progress. The data presented in this paper, therefore, show the effects not only of sewage interception and treatment, but also, the effect of a reduction of the total pollution load on the Niagara River.

Bacterial Data

In order to simplify the presentation and discussion of the data, the actual bacterial results obtained at the sampling stations at a single series were averaged. These data are presented in Tables 2 and 3. They show the cross-sectional average coliform and total bacterial content per milliliter at Series EE and Series H. The data for the four years, 1936–40, listed in these tables are plotted in Figs. 2 and 3, which show graphically the conditions before and after sewage treatment and disinfection.

TABLE 2

Cross-Section Average Coliform M.P.N. per ml. at Series EE and H, 1936–40

MONTH	1936	1936-37	1937-38	1938-39	1939-40
Series EE					
July	—	295	335	900.00	7.90
August	—	470	265	440.00	35.00
September	—	890	385	51.00	5.35
October	—	1680	555	25.00	7.15
November	—	180	75	6.85	9.85
December	—	120	80	7.45	12.70
January	—	180	68	4.95	2.85
February	—	270	165	4.58	18.80
March	—	240	155	5.30	3.30
April	—	65	50	6.80	8.20
May	—	100	50	3.50	2.45
June	230	325	180	7.40	—
Average, June, 1936–August, 1938					323.0
Average, September, 1938–May, 1940					11.2
Reduction, %					96.5
Series H					
July	—	45	95	575.00	25.70
August	—	42	110	200.00	27.60
September	—	70	310	64.50	19.70
October	—	125	—	14.50	48.60
November	—	164	65	10.60	11.70
December	—	95	275	8.65	9.80
January	—	225	110	6.70	1.90
February	—	120	—	11.90	24.00
March	—	55	135	11.50	3.10
April	—	115	80	17.90	11.30
May	—	45	80	5.00	2.33
June	40	100	75	5.35	—
Average, June, 1936–August, 1938					134.0
Average, September, 1938–May, 1940					16.3
Reduction, %					87.9

TABLE 3

Cross-Section Average Total Bacterial Content per ml. at Series EE and H, 1936–40

MONTH	1936	1936-37	1937-38	1938-39	1939-40
Series EE					
July	—	3,840	2,820	5,610	860
August	—	1,000	9,280	21,000	2,000
September	—	10,900	13,300	2,870	1,240
October	—	1,850	1,970	2,800	990
November	—	2,400	1,440	500	420
December	—	1,420	540	—	155
January	—	520	240	—	33
February	—	390	230	60	65
March	—	475	570	70	28
April	—	410	580	45	58
May	—	660	4,170	75	406
June	570	1,600	35,200	1,370	—
Average, June, 1936–August, 1938					4,590.0
Average, September, 1938–May, 1940					739.0
Reduction, %					83.9
Series H					
July	—	820	2,070	1,820	560
August	—	140	3,860	1,830	2,800
September	—	1,530	2,540	2,220	3,450
October	—	220	—	3,580	3,460
November	—	730	1,190	129	410
December	—	175	730	—	90
January	—	560	495	—	33
February	—	120	—	225	95
March	—	170	305	25	27
April	—	310	550	200	59
May	—	585	1,980	40	312
June	615	955	8,810	480	—
Average, June, 1936–August, 1938					1,320.4
Average, September, 1938–May, 1940					957.0
Reduction, %					27.5

It is indicated by these data and curves that following the inauguration of sewage treatment at Buffalo, beneficial effects were not immediately observed in the Niagara River. There were two possible causes for this condition. The first was the fact that, in the Buffalo River, polluted wastes which had accumulated prior to July, 1938, continued to be discharged for some months, thereby affecting the Niagara River. The second was that complete control of sewage chlorination was not established immediately, although some chlorine was being added to the sewage. Effective control of

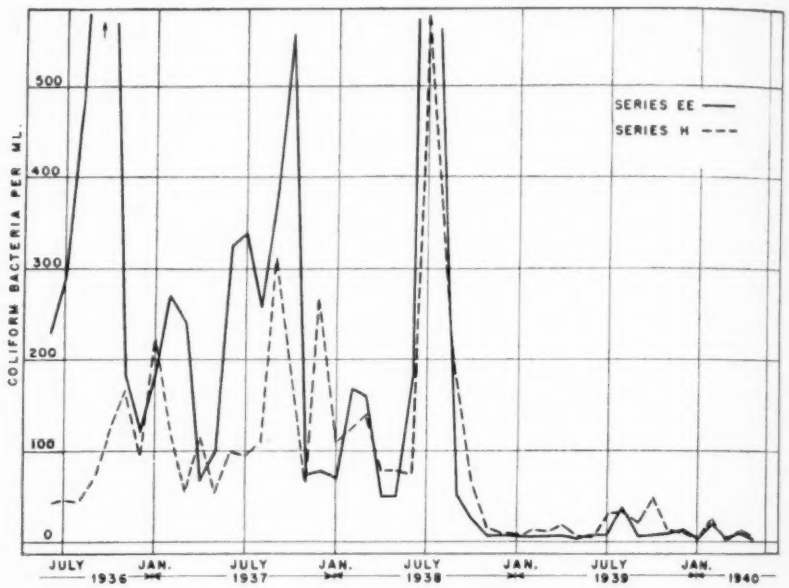


FIG. 2. Coliform Bacteria, M. P. N., Niagara River, 1936–40

bacterial pollution of the Niagara River has been continuous since definite improvement in the river was established.

Referring to the averages in Table 2, it is shown by the data that the number of coliform bacteria existing in the Niagara River under present conditions is well within the International Boundary Commission limits specifying an average cross-sectional content of 5 per ml., although within the polluted zone the coliform content is approximately twice that value.

Using the arithmetical averages of the bacterial data per milliter

before and after the time when interception, treatment and disinfection of Buffalo sewage became effective, it appears that the coliform content was reduced 96.5 per cent at Series EE, but only 87.9 per cent at Series H. As might be expected, the reduction in the total bacterial count was less than that for coliform bacteria. The reduction in total count was 83.9 per cent at Series EE and 27.5 per cent at Series H. The greater coliform and total bacterial contents at Series H than at Series EE indicates that pollution intro-

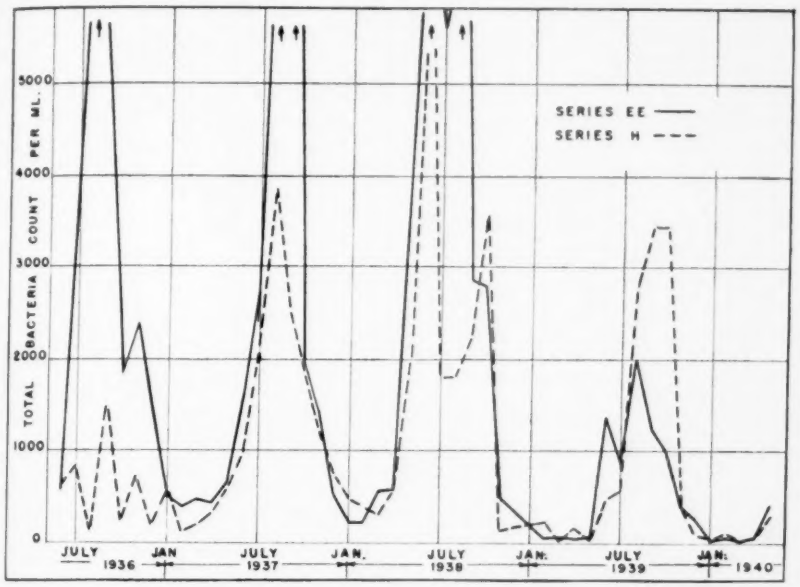


FIG. 3. Total Bacteria Counts, Niagara River, 1936–40

duced below Buffalo has some effect on the Niagara River at Niagara Falls.

The true evaluation of the reductions of pollution of the Niagara River cannot be obtained from arithmetical averages of the bacterial content per milliliter. Therefore, the data were calculated to quantity units at Series EE, where data were available on the actual flow in the various sections of the river represented by the different samples. As shown in Table 4, the reduction on the quantitative basis was 97.1 per cent. This reduction is shown graphically in Fig. 4 wherein the quantity units of coliform bacteria at Series EE are plotted. The general trend of this curve is similar to that in Fig. 2,

TABLE 4

Total Quantity Units of Coliform at Series EE, 1936–40

MONTH	1936	1936–37	1937–38	1938–39	1939–40
July	—	11,524	15,100	38,940.0	380.0
August	—	13,329	9,360	18,490.0	1,805.0
September	—	50,187	18,700	1,200.0	137.0
October	—	62,503	20,900	1,100.0	450.0
November	—	9,317	2,320	255.0	334.0
December	—	5,888	3,530	420.0	450.0
January	—	3,360	1,184	153.0	65.4
February	—	12,900	3,946	69.3	415.0
March	—	6,730	7,020	82.8	112.0
April	—	4,550	2,548	92.2	292.0
May	—	4,370	4,934	54.6	96.0
June	10,863	10,000	8,520	330.0	—

Average, June, 1936–August, 1938	13,360.0
Average, September, 1938–May, 1940	395.0
Reduction, %	97.1

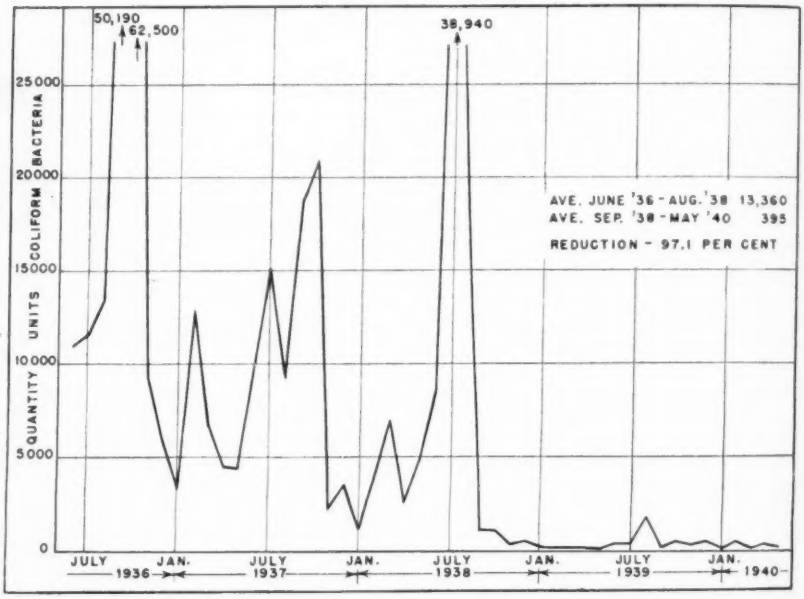


FIG. 4. Total Coliform Bacteria in Niagara River at Series EE, 1936–40

but these latter data take into account the variations in the flow of the river.

During the summer months, samples were collected from a boat at several locations in addition to Series EE and Series H. One of these locations was 2.7 miles above Series EE, at Series E, where the flow in the various sections of the river had also been measured, and where it was, therefore, possible to determine the quantity units. Before sewage treatment went into effect, it was observed that the coliform content of the river increased between the two stations. Since sewage treatment has been practiced, however, the summer data indicate that this increase has been eliminated. Actually, there now appears to be a slight decrease.

It was also observed on the basis of the summer data, in 1939, that at Series E, the coliform content had been reduced by 96.2 per cent from that existing in summers of 1936–37–38. At Series EE, the summer data of 1939 show that the coliform content had been decreased by 97.6 per cent. These data indicate that in the warm weather months, when growths might be expected to be more prolific, the improvement in stream conditions was approximately the same as the average for the entire year.

All summer data on coliform and total bacteria count, including those collected at Series BB, C and D, are shown in Table 5. These figures give three indications. First, at Stations BB, above the sewage treatment works, they show that the effect of the Buffalo River and of pollution from the lake still exists at times, particularly during storms. Second, they illustrate that the bacterial concentrations, existing above the sewage treatment works, affect the results obtained below the treatment works. Inasmuch as sewage treatment cannot remove pollution already in the Niagara River, the utilization of data so affected actually operates as a penalty in calculating reductions due to sewage treatment. On the assumption that some of this pollution was from the Buffalo River, this penalty was accepted in the interpretation of the data. Third, the data indicate that the reduction in bacterial content of the Niagara River exists throughout its entire length.

In Part 1 of this paper the relative distribution of coliform bacteria within the pollution zone was shown. For comparative purposes, those data are repeated in Table 6, together with data for the period since sewage treatment began. All data are for the warm

TABLE 5

Average Bacterial Concentration per ml. at Each Series
(Summer Data)

DATE	SERIES					
	BB	C	D	E	EE	H
Coliform per ml.						
July, 1938	80.60	915.00	85.90	510.00	900.00	575.00
Aug., 1938	1.42	300.00	242.00	280.00	440.00	200.00
Sept., 1938	80.00	42.00	88.00	19.00	51.00	64.00
Oct., 1938	91.00	47.00	7.34	10.30	25.00	14.50
Nov., 1938	9.11	8.70	2.01	2.53	6.84	10.60
June, 1939	3.11	4.18	1.82	4.86	7.39	5.34
July, 1939	0.83	4.31	3.31	3.01	7.90	25.70
Aug., 1939	31.80	35.30	34.00	21.70	30.00	27.60
Total Count						
July, 1938	530	2,950	825	730	5,610	1,810
Aug., 1938	510	6,970	1,030	3,570	21,000	1,830
Sept., 1938	450	2,340	1,560	1,980	2,870	2,220
Oct., 1938	1,100	1,870	1,100	60	2,800	3,580
Nov., 1938	1,010	450	470	216	500	129
June, 1939	443	694	294	317	1,370	480
July, 1939	435	499	693	378	860	560
Aug., 1939	1,820	1,420	1,022	643	2,000	2,800

TABLE 6

Relative Distribution of Coliform Bacteria per ml. From the American Shore
(Warm Water Data Before and After Sewage Treatment at Buffalo)

TEST STATION AND DISTANCE FROM PEACE BRIDGE	0–200 FT. FROM SHORE		200–500 FT. FROM SHORE		500–900 FT. FROM SHORE		900–1,300 FT. FROM SHORE		1,300–1,700 FT. FROM SHORE	
	Before	After	Before	After	Before	After	Before	After	Before	After
Series BB, 0.6 mi.	350	24	0.8	0.6	0.9	0.63	0.35	—	0.30	—
Series C, 1.4 mi.	1,040	23	3,200.0	12.0	1,000.0	26.00	12.00	9.0	10.00	5.0
Series D, 3.2 mi.	500	21	700.0	11.0	390.0	7.00	15.00	1.1	1.00	0.5
Series E, 4.1 mi.	550	25	550.0	11.0	335.0	6.00	15.00	1.0	4.00	1.6
Series EE, 6.3 mi.	730	18	870.0	29.0	70.0	4.90	0.25	1.0	—	—
Series F, 9.7 mi.	540	—	280.0	—	18.0	—	4.00	—	—	—
Series H, 16.7 mi.	530	50	165.0	16.0	135.0	27.00	40.00	2.5	16.00	2.4
Average, Series C–H inclusive	670.0	27.4	1,097.0	15.8	386.0	10.3	16.4	2.9	7.7	2.4
Reduction below BB, %		95.9		98.6		97.4		83.4		69.0

water observations (June–October). Distances represented by the samples are approximate. The data indicate that:

1. The discharge of disinfected sewage 200 ft. offshore at the treatment plant does not extend the pollution line any further into the river than before treatment, i.e., approximately 30 per cent of the total flow of the Niagara River.
2. There is still some shore pollution (apparently some comes from the Buffalo River).
3. Regrowth of bacteria is not strongly evident. (This confirms experiments previously reported (4) from this laboratory.)
4. Since Buffalo sewage treatment began, the entire Niagara River has been designated as a Class A water as defined by the United States Public Health Service (5) on the basis of coliform content. Prior to 1938, the data show that on a coliform content basis, the river was a Class C water up to approximately 900 ft. offshore and a Class A water outside that limit. It has, however, always been a Class A water on a D.O. and B.O.D. basis.
5. There has been a reduction in coliform bacteria content in all sections of the Niagara River included within the pollution zone.
6. Shore pollution and sewage from towns below Buffalo is apparent at Series H.

Sewage Treatment and Other Data

A short discussion of the treatment which has accomplished these improved stream conditions is essential to the picture of the project of pollution abatement. Table 7 presents operating data on the days when river surveys were made. Inasmuch as the samples collected from Series H represented water that had passed the treatment plant, some 12 hours previous to sampling, the data on operation are presented as an average of the day previous and the day of the survey.

The data in Table 7 show the wide variations in operating conditions with the relatively constant bacteriological disinfection, except during storm sewage treatment when the kill may be reduced somewhat. It is interesting to compare these random data with the average of the daily operating data for 1939. This comparison, as shown in Table 8, indicates that normal operation existed at the times of the various river surveys.

In Part 1 of this report, it was pointed out that under summer conditions there was a large increase in the coliform content of the Niagara River as it proceeded downstream after receiving the sewage

TABLE 7

Sewage Treatment Operation Data at Times of Niagara River Surveys

DATE	FLOW	CHLORINE DOSAGE	COLIFORM CONTENT PER ML.		COLIFORM QUANTITY UNITS		
			Raw	Effluent	Raw	Effluent	% Kill
	m.g.d.	*lb./day*					
1938							
July 8–9	114*	—	—	—	—	—	—
Aug. 8–9	138	—†	297,000	208,000	62,600	46,600	25.56
Sept. 12–13	116	5,560	172,000	1,390	30,800	232	99.24
Oct. 10–11	106	4,950	295,000	1,820	31,300	300	99.05
Nov. 1–2	103	7,740	76,500	4,550	12,200	728	94.03
Dec. 6–7	181	9,460	33,500	400	8,180	148	98.19
1939							
Jan. 17–18	115	4,420	26,500	0.12	4,670	0.02	99.99
Feb. 21–22	175	3,140	12,100	17	3,200	4.7	99.85
Mar. 14–15	196	5,700	26,200	298	7,750	85	98.90
Apr. 4–5	135	3,370	31,700	1,080	6,640	215	96.76
May 9–10	134	5,090	32,000	1,380	6,530	292	95.52
June 7–8	103	5,070	49,400	1,860	7,820	295	96.22
July 12–13	135	7,480	68,000	413	41,300	287	99.30
Aug. 11–12	117	7,450	207,000	17	37,200	12	99.96
Sept. 13–14	120	10,800	156,000	618	27,300	116	99.57
Oct. 11–12	131	6,650	43,000	2,411	8,100	675	91.66
Nov. 14–15	130	8,360	41,300	2.9	8,380	0.5	99.99
Dec. 13–14	128	6,170	35,700	317	7,280	71	99.02
1940							
Jan. 9–10	130	5,390	89,900	56	18,800	5.5	99.97
Feb. 20–21	214	3,260	27,500	7,260	9,660	1,270	86.85
Mar. 24–25	140	2,590	15,200	34.3	2,720	10	99.63
Apr. 16–17	191	3,410	40,500	3,270	12,500	840	93.28
May 14–15	136	4,560	43,600	107	9,010	30	99.66
Average‡	139	5,743	72,500	1,300	14,350	267	98.13

* No other data.

† Recorders inoperative.

‡ Excluding July and August, 1938.

from Buffalo. Since July 1938, in comparison of the average coliform discharge in the sewage at the times of river surveys (267 quantity units) with the average at Series EE (397 quantity units), there has appeared to be little, if any, re-growth or increase of coliform bacteria discharged into the river. The apparent increase may be, at least partly, due to bacteria present in the river above the sewage treatment works outfall.

That some of these bacteria come from the Buffalo River is true. Comparative studies (3), however, show that, whereas the discharge of the Buffalo River prior to July, 1938, carried 10,000 to 20,000 coliform per ml. and a 5-day B.O.D. pollution load equivalent to 245,000 persons, it now carries approximately 2,500 coliform per ml. and a pollution load of approximately 95,000 persons.

TABLE 8

Comparison of Average Operating Data With Data at Times of River Surveys

ITEM	AVERAGE, 1939	AVERAGE AT TIMES OF SURVEYS*
Flow, *m.g.d.*	130	139
Chlorine dose, *lb./day*	5,600	5,743
Coliform per ml. (raw)	75,000	72,500
Coliform per ml. (effluent)	1,040	1,300
Coliform Quantity Units (raw)	15,100	14,350
Coliform Quantity Units (effluent)	210	267
Kill of coliform, %	98.6	98.13

* Excluding July and August, 1938.

With the removal of some 90,000 to 100,000 pounds of dry solids from the sewage before discharge (disinfected) into the Niagara River, the turbidity of the river in the pollution zone has decreased. This improvement has resulted in increased use of the river for fishing, swimming and other recreational uses.

In order further to gage the improvement in the Niagara River and its effect on cities below Buffalo, a study was made of the operating data of the filter plants for the three years, 1937, 1938 and 1939, at Tonawanda, North Tonawanda, Lockport and Niagara Falls.

Because of the fact that 1938 represented a year which witnessed the change to sewage treatment, only the years 1937 and 1939 may be compared in their entirety. The comparison of data for two single years always entails difficulty since many variables besides the

one of particular importance, i.e., sewage treatment at Buffalo, might affect the results, but the data on bacterial loads are gratifying in their indications.

The water intakes of Tonawanda, North Tonawanda and Lockport are all outside the general pollution zone, except as its boundary line is affected by wind conditions and storm flows from the Buffalo River. Normally, then, it might be expected that any effect on general plant operation due to sewage treatment at Buffalo would be less than the normal variation in operating conditions between any two years. Effects of the shifting boundary of the pollution zone, with attendant bacterial peak loads, should be observable from the data. The Niagara Falls intake is within the outskirts of the pollution zone, and the greatest change in bacterial load was expected at that point.

When the data for the several plants were tabulated for comparison, it appeared that, as far as plant operation and chemical dosages were concerned, the differences were within possible normal variation. On the basis of bacterial data, however, the studies indicate great improvement in the condition of the river after July, 1938.

At Tonawanda and North Tonawanda, bacterial tests are made weekly. The Tonawanda department sent samples to the Buffalo city laboratory in 1937, but made analyses in its own laboratory in 1939. At Lockport, bacterial tests are made daily, but these are made on samples that have been pre-chlorinated in the raw water suction well and have had about 12 hours chlorine contact time. At Niagara Falls, bacterial tests are made daily. All laboratories use only 3 tubes of one dilution for coliform tests. These variations and factors were taken into consideration in interpreting the data. Where only one dilution was used for coliform tests, it was assumed, for purposes of estimating the M.P.N. of coliform, that the next highest dilution were all positive tubes and the next lowest dilution were all negative tubes. This assumption admits of some error but the data thus obtained are indicative.

At Tonawanda and North Tonawanda, the variations in coliform bacteria were probably normal, but both plants showed appreciable decreases in total bacterial count. Of more and vital significance was the apparent elimination of peak bacterial loads, a condition of extreme sanitary importance.

Detailed study of the individual data indicates that Tonawanda

experienced many peak bacterial loads in 1937. Several ranged from 25,000 to 42,000 per ml. Since July, 1938, however, peaks have been infrequent and only one reached 4,800 per ml. At North Tonawanda, in 1937, peak loads ranged from 2,800 to 4,500 per ml., whereas, in 1939, peak counts were almost absent with none above 1,500 per ml. The Lockport intake is furthest outside the pollution zone, but the pre-chlorinated water showed a decrease in positive presumptive coliform organisms.

The most interesting and significant data are those from Niagara Falls, where the intake is just within the boundary of the pollution

TABLE 9

Bacterial Content of Intake Water at Niagara Falls

MONTH	COLIFORM PER ML.					TOTAL COUNT PER ML.				
	1936	1937	1938	1939	1940	1936	1937	1938	1939	1940
January	14.8	17.3	14.2	0.91	0.60	310	400	260	190	180
February	23.4	9.9	20.2	11.6	0.69	400	300	240	320	120
March	15.9	17.6	16.7	10.9	1.01	390	240	370	220	213
April	11.6	21.1	9.9	2.24	1.14	370	200	530	210	164
May	10.4	7.8	10.2	0.61	—	290	220	620	240	—
June	19.9	35.5	19.1	0.75	—	740	420	320	240	—
July	77.9	54.9	23.7	0.49	—	860	450	710	240	—
August	75.7	57.6	24.3	0.91	—	1090	330	690	190	—
September	82.5	45.4	18.6	0.80	—	940	580	580	200	—
October	72.5	27.1	6.9	0.91	—	380	400	300	270	—
November	21.2	18.0	1.66	0.69	—	390	280	430	410	—
December	14.2	16.7	0.87	1.06	—	180	280	250	260	—
Average	36.7	27.5	13.8	2.62		530	350	440	250	

zone. Daily data were collected and these permitted the use of monthly and yearly averages for comparative purposes in the estimation of per cent improvement. The data for 1936–37 (1) were obtained especially for the Sewer Authority. Data for 1938, 1939 and 1940 have been made available for these studies. These data are graphic in their testimony as to the improvement in the river. Summaries for the four years and four months are presented in Table 9 and plotted in Fig. 5.

The reduction in coliform, as shown by comparing 1939 data to the average for 1936–37 is 91.6 per cent, which figure is not far different from the data on the river surveys (Table 2) that indicated an

87.9 per cent reduction. The frequency and magnitude of peak loads were decreased. The high bacterial counts and coliform contents, which occur regularly in February, March and April, appear to be due to shore ice pushing the pollution (particularly from towns between Buffalo and Niagara Falls) further out into the river. This pollution, from other sources than Buffalo, explains why the improvement in the river at Niagara Falls is not as great as at the upper Grand Island Bridge.

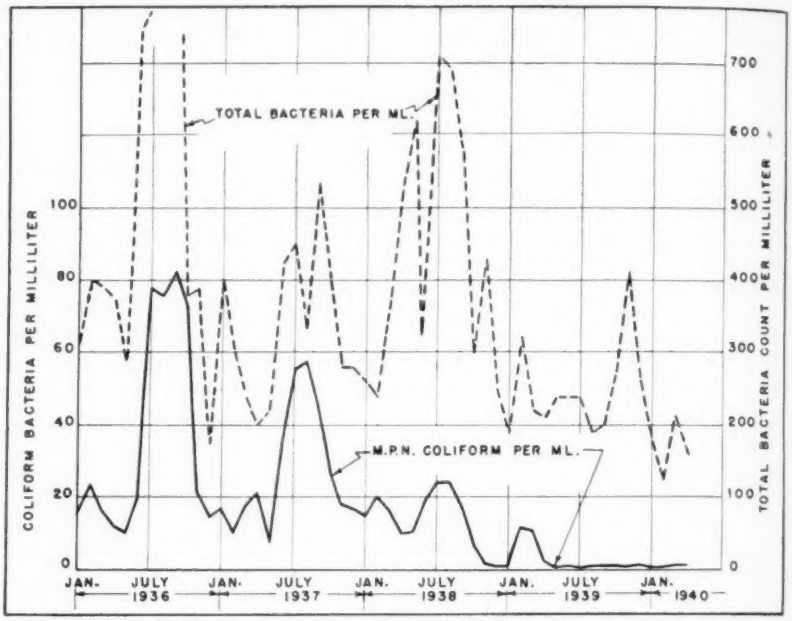


FIG. 5. Monthly Average Bacterial Counts at Niagara Falls Water Intake, 1936–40

Information was obtained from two of the industrial plants which take water from near the shore below Buffalo. One reports that, since July, 1938, the turbidity has decreased, on the average, from 25 to 10 p.p.m.; alum consumption has decreased 25 per cent; the bacterial load has decreased 25 per cent (there is still some effect of shore pollution), and the chlorine demand has decreased considerably "under normal conditions," i.e., except during storms and flood effects from Buffalo River. The other plant reports a reduction in suspended solids from 49 to 24 p.p.m. and an average reduction in chlorine demand of 50 per cent.

Summary and Conclusions

A comparison of studies of the Niagara River for a period of 23 months since July 1, 1938, with data for a period of 25 months before that time, i.e., before and since sewage treatment was inaugurated at Buffalo, indicates the following pertinent facts:

1. The coliform content of the Niagara River below Buffalo has been reduced by approximately 97 per cent. This has been effected by: (a) interception of sewage to remove it from the Buffalo River, Buffalo Harbor, Black Rock Canal and the Niagara River; (b) treatment and disinfection of the sewage by an average of approximately 5,600 lb. of chlorine per day which kills approximately 98.5 per cent of the coliform bacteria and 97.5 per cent of the total bacteria; and (c) partial removal of industrial wastes from the Buffalo River.

2. The total bacterial content of the Niagara River has decreased by approximately 84 per cent for the same reasons as above.

3. The Niagara River, below Buffalo and above Tonawanda, is a Class A water, as defined by the U. S. Public Health Service. The coliform bacterial content now will meet the standards for average cross-sectional content set by the International Boundary Commission.

4. The discharge of the chlorinated and settled effluent, 200 ft. offshore, does not extend the pollution boundary line any further into the river; and such bacterial content as remains is still within the limit of 30 per cent of the total flow of the river.

5. Strong winds and flood flows from the Buffalo River may still push the pollution line beyond its normal boundary, but water plants below Buffalo experience no peak bacterial loads such as existed before 1938.

6. The bacterial condition of the raw water at the Niagara Falls Filtration Plant has improved by approximately 90 per cent as to coliform bacteria. This supply may be expected to show further improvement when sewage treatment plants between Buffalo and Niagara Falls are completed.

7. The removal of approximately 50 tons daily of dry solids from the river has resulted in a clearer stream more conducive to recreational uses.

The Bird Island Laboratory is indebted to the following persons for supplying data and information on water supplies and water filtration plants: Henry Wagner, Chief Chemist, Division of Water, Buffalo; Frank Korff, Chief Engineer, Tonawanda Water Works;

Fred Grant, Plant Superintendent, North Tonawanda Filtration Plant; Roger Foltz, Chemist in Charge, Lockport Water Works; Bert T. Dignan, Superintendent and Chemist, Niagara Falls Filtration Plant.

References

1. Symons, G. E. and Simpson, R. W. Bacterial Pollution of the Niagara River. Part 1. Conditions Before Sewage Treatment at Buffalo, N. Y. Jour. A. W. W. A. **31:** 1156 (1939).
2. *Standard Methods of Water Analysis*, (8th Edition). A. P. H. A. and A. W. W. A., New York (1936).
3. Symons, G. E. and Torrey, Wm. L. Buffalo River Stream Pollution Studies, 1936-1939. Sewage Works Jour. **12:** 586 (1940).
4. Symons, G. E., Simpson, R. W. and Torrey, Wm. L. Reduction of Bacteria in Sewage by Chlorination. W. W. and Sew. **85:** 983 (1938).
5. Streeter, H. W., Carnahan, C. T. and DeMartini, F. E. Application of Laboratory Data to Pollution Abatement Programs. Paper presented before the Division of Water, Sewage and Sanitation Chemistry at the 99th meeting of the American Chemical Society, Cincinnati, Ohio, April 8-12, 1940.

The Effect of Internal Pipe Lining On Water Quality

By Paul Weir

IN THE United States some 13,000 individual water works systems supply water to 81,000,000 people. Obviously, in handling and distributing this commodity from source to consumer a major transportation problem is involved. The transportation system must be most efficient and economical and it is also essential that there be no serious impairment of quality of the product during the transportation process. Effective purification and sterilization methods are of little value, if the painstakingly achieved water quality is significantly altered during transportation. Precise engineering of the transportation system is difficult if there is progressive loss of efficiency with use. The pipe line normally affords the most efficient and economical medium of transportation, but careful consideration must be given to: (1) possible impairment of the water quality by contact with the pipe wall; and (2) the possible reduction of the pipe line efficiency by contact with the water. The first of these considerations, water quality, is the primary concern of this paper. Since corrosion is usually the underlying cause of both effects, however, there is indirect evidence concerning the continuance of pipe efficiency.

A common effect of ferrous pipe lines on water is to increase the iron content causing red water and staining of plumbing. Waters vary considerably in their tendency toward this effect. Hard or alkaline waters have little or no tendency toward becoming red, while soft or acid waters attack iron readily. The Langelier Index (1) is probably one of the best available criteria for evaluating this tendency. Rate of flow has a pronounced effect on red water formation since this factor determines the contact of the water with iron.

A paper presented on April 25, 1940, at the Kansas City Convention by Paul Weir, Superintendent of Filtration, Atlanta Water Works, Atlanta, Ga.

In many systems it is only the water from slow-flow "dead-end" mains which shows appreciable iron staining.

Linings for ferrous pipe may considerably reduce or even prevent red water formation but there is also the possibility that the lining may alter the water quality in some way, as by causing taste and odor or by radically changing the hardness, alkalinity, or pH. Similarly, use of non-ferrous piping will undoubtedly eliminate iron stain, but in some cases desirable quality characteristics of the water may also be altered. In many industries served by city supplies (e.g., textile industries) constant quality of pure water is essential. It is generally true that *any* radical change in water, which is purified to the desired quality, will occasion complaints from some users.

Another adverse effect of interior corrosion on ferrous piping is tuberculation and the reduction of the flow capacity of the pipe line. Wherever corrosion is taking place, as evidenced by red water or increase in iron content, there is also tuberculation. Iron corrodes in water by localized pitting. Above each pit where ferrous ions are formed, contact with oxygen dissolved in the water precipitates the greater part of the dissolved iron as insoluble ferric hydroxide forming a protuberance or tubercle over the pit (2). By this mechanism there is formed above each pit a tubercle which is many times the size of the underlying cavity. The result of innumerable tubercles on the interior pipe surface is reduction of flow by friction causing loss in carrying capacity and decreased efficiency. Flow of water through smooth pipe and through tuberculated pipe may be compared to the relative ease of a man walking over pavement and over ploughed ground. The loss of flow coefficients of a ferrous pipe by tuberculation may often amount to as much as 30 to 50 per cent in 15 to 30 years (3).

Use of Langelier Index

The criterion used in determining the tuberculating effect of a water is, of course, the same as that used for the red-water-forming tendency and is well expressed by the Langelier Index. Many waters which are relatively hard or alkaline are not serious causes of tuberculation in ferrous pipe. Occasionally, the very hard or alkaline waters cause reduction in carrying capacity by precipitating calcium carbonate on the walls of the pipe. This is rare; however, for most waters show a slight tendency toward tuberculation by corrosion. Tuberculation is also a factor to be considered in the raw water lines

where red water is of no moment. Soil corrosion experience indicates that the useful life of cast iron pipe may be materially curtailed if the flow capacity of the pipe is seriously impaired by tuberculation within a few years.

Chemical treatment of water to a Langelier Index of zero ($CaCO_3$-solubility equilibrium) is often used to stop tuberculation and red water in ferrous pipes. In some soft waters, however, this is not practicable and, when used, is not always completely effective (4). In those cases where water, after treatment, is still of such quality that serious tuberculation and red water occur in ferrous pipe, the remedy is obviously either in a lining which will stop interior corrosion without seriously affecting other quality characteristics of the water, or in use of a non-ferrous pipe which also should not otherwise adversely affect the water quality.

Purpose of Tests

The tests herein described were started in May, 1937, to evaluate the effect of Atlanta water on passage through various types of pipe materials and various types of interior linings for pipe. Hoover (5) made tests to evaluate the internal corrosion of hot water heating tanks, and Hale (6) made extensive tests on service piping in various waters. Donoho (7) is conducting a fill and drain test on 6-inch pipe in Birmingham. The present tests at Atlanta, however, include various water main materials (6-inch pipe) as well as service piping ($\frac{3}{4}$-inch pipe) and also many types of interior linings.

The purpose of these tests is to evaluate both the efficacy in resisting corrosion and the possible effect on water quality of the various pipe materials which might be installed in the Atlanta system. The performance of a pipe material in some such simple test set-up as herein described is a useful guide to the selection and use of pipe materials for actual service in the same water.

Test Methods

In July, 1939, about 200 copies of a "Progress Report on the Atlanta Water Works Tests" were sent out to interested parties and recognized authorities for criticism and suggestions. The replies were deeply appreciated by the authors (8), and in this paper consideration has been given to the criticisms and suggestions received.

Purified and filtered water from the Atlanta Water Works, taken at the entrance to the distribution system, is passed through a pipe

specimen under test and allowed to drip from an outlet tap on a white porcelain plate. Figure 1 shows the detailed arrangement of one 6-inch test unit.

Since rate of flow, or time of contact, affects the iron concentration in red water, and since red water complaints in the Atlanta system occur usually in dead-end areas, the flow in the tests was made to correspond with that of an average dead-end main, rather than that of a high-demand section of the system. The rate of flow adopted was determined by actual tests on dead-end mains and is controlled at 112 drops per minute from the outlet sample tap. At this rate, water passes through the 2-ft. long 6-inch diameter specimens in an average time of 8 hr. and through the $\frac{3}{4}$-inch service pipe specimens, 47 ft. long, in about 3 hr.

The inlet manifold line is $\frac{3}{4}$-inch copper pipe and the taps shown in Fig. 1 are brass reducer bushings. Pressure is about 30 to 35 lb

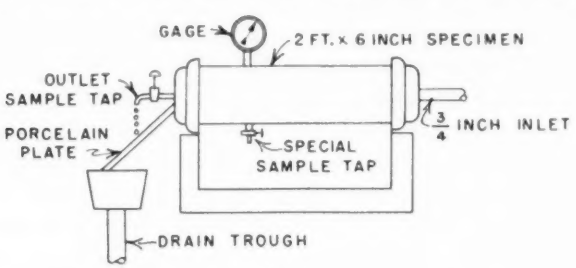


FIG. 1. Detail of Test Unit for 6-Inch Pipe

per sq. in. Exceptions to the test set-up as outlined are: Specimens No. 1 in which the pipe is 8 in. in diameter, and No. 17 in which the rate of flow is exactly twice that in the other 6-inch units. There are 44 specimens in the test at present. Test results are obtained by examining the staining of the white plates under each unit and by comparing effluent water analyses from each unit with the influent purified water.

In discussing the first progress report of these tests, the question was raised as to the effect of possible galvanic currents arising from the connection of $\frac{3}{4}$-inch copper headers to the various ferrous and other pipe specimens. Measurements of potential between the copper headers and the various specimens showed varying results in the order of .001 to .0001 volt, the copper header being generally positive to the specimens. It has been suggested that 1–$1\frac{1}{2}$ volts

would not be hazardous. It is very doubtful, however, that these low potentials are significant in affecting the results, and even if they are, they do not detract from the value of the tests, since copper services are used in connecting Atlanta mains so that the same effect would be found in actual service.

Analytical data are obtained by sampling the effluent water at the outlet tap of each test unit and comparing the results of analyses and tests with those on the purified influent water. Each unit is sampled at least once a month, and usually more frequently, at the beginning of the test. Analyses and tests made on each sample are as follows: turbidity, color, hardness, temperature, CO_2, pH, iron, and total alkalinity. Determinations of dissolved oxygen, residual chloramine, and phenolphthalein alkalinity were started in July, 1938. Determination of total solids on all samples was begun in October, 1939. For comparison with the determinations on the effluents from the test units, analysis of the Atlanta tap water, which is introduced into the test units, is shown in Table 1. The values shown are averages of many tests in each case, as frequent tests are run daily, from one test per day for iron content up to 90 tests daily for residual chloramine and 98 daily pH determinations. The approximate Langelier Index of this water, as determined by a continuous operating Enslow stabilizer, is in the range of -0.4 to -0.8, indicating that the water is expected to be mildly corrosive to iron.

Test Units

The test units were procured by circularizing interested pipe manufacturers and allowing each company to submit test sections of the particular types of pipe best suited for aggressive water service. All sections were received, from the manufacturers, closed and tapped for connections. They were installed as received so that all responsibility for the condition of the lining and the protection of the inside surface of the caps would be the sender's. This method, although perfectly fair, does introduce another variation into the tests, i.e., the care exercised by the manufacturers in preparing test sections. In a few instances this may have obviated accurate comparison of materials. A 2-inch sample section ring of each pipe tested is mounted at the back of each test unit so that the kind of pipe and nature of the lining may easily be seen. As control samples, two sections of 6-inch cast iron pipe, which have been in service for 30 years in Atlanta water mains, were installed as Units No. 6 and

No. 17. This pipe had a tar dip lining originally, but at the time of installation none of the former lining was visible and severe internal corrosion and tuberculation was evident. Ordinary new black steel and galvanized steel tubing are used as controls for the service pipe tests. These are Units No. 21 and No. 22. Table 2 shows the significant data on the materials tested.

TABLE 1

Atlanta Water Works
Tap Water Analysis—1939

(Values expressed in parts per million except as otherwise noted.)

	TURBIDITY	HARDNESS	CARBON DIOXIDE	pH	IRON	RES. Al_2O_3	OXYGEN % SAT.	ALK. M. O.	RES. CHLORAMINE	TEMP. °F.	
										Air	Water
Ave. for 1938	.25	23.5	0	8.5	.015	.028	93.4	14.9	.31	61.9	64.4
January, 1939	.3	23.5	0	8.5	.01	.02	95.2	14.9	.26	44.7	45.4
February	.3	23.4	0	8.5	.01	.02	95.0	13.0	.24	49.3	51.3
March	.3	22.4	0	8.5	.01	.02	98.4	13.7	.26	55.2	55.0
April	.28	22.2	0	8.5	.02	.04	94.0	14.1	.26	60.2	62.0
May	.3	24.0	0	8.5	.02	.03	91.6	14.3	.26	65.4	68.0
June	.2	23.6	0	8.5	.02	.03	89.0	15.8	.27	74.0	75.7
July	.3	25.0	0	8.5	.03	.03	89.2	16.1	.39	78.3	82.1
August	.3	24.0	0	8.5	.02	.03	88.9	15.1	.38	76.0	77.6
September	.2	24.5	0	8.5	.02	.01	90.0	16.3	.38	75.1	78.3
October	.2	25.0	0	8.5	.02	.02	91.5	17.5	.35	68.0	69.2
November	.2	25.2	0	8.5	.02	.02	87.0	17.5	.41	50.3	51.2
December	.2	25.6	0	8.5	.02	.02	95.5	17.9	.36	49.1	47.3
Ave. for 1939	.27	24.0	0	8.5	.018	.024	92.1	15.5	.32	63.2	63.4
Seasons:											
Winter	.27	24.1	0	8.5	.013	.02	95.2	15.3	.29	47.7	48.0
Spring	.29	22.9	0	8.5	.013	.03	94.7	14.0	.26	60.3	62.0
Summer	.27	24.2	0	8.5	.023	.03	89.0	15.7	.34	76.1	78.5
Fall	.20	24.9	0	8.5	.02	.016	89.5	17.1	.38	64.5	66.2

There are four types of stain identified by this test: (1) red staining of the white porcelain plates under test units is the most direct measure of the solution of iron from pipe sections; (2) leaching of alkalis from cement in the case of cementitious,* or cement lined,

*"Cementitious" is used here to differentiate cement-manufactured pipe from cement-lined metal pipe.

pipe causes a dark or dark-gray stain; (3) dezincification of galvanized pipe causes a dull metallic stain; and (4) in addition, there is an unavoidable gray stain caused by dust which gives a faint gray halo on each of the plates, regardless of the specimen. These four types of plate stain are represented by typical specimens in Fig. 3—(1) No. 12, (2) No. 1, (3) No. 7, and (4) No. 3. The appearance of the plates, as reproduced by black and white photographs, is shown in Figs. 2A, 2B and 3. The brief identification of each test specimen shows: first, the number of the specimen corresponding to its complete identification in Table 2; second, the general type of pipe material; and third, the type of lining, if any. The length of time under test for each section, which is shown in Table 2, should be considered in any comparison of staining.

Data Obtained

The analytical data, determined on the effluent from each test unit, are given in Table 3 at the end of the paper. Individual analyses are shown for the first month and after that average values for three months at a time are given. This method of presentation shows the salient data, since after the first month the rate of change of analytical values markedly decreases.

Water quality is affected in its passage through the pipe. This is evaluated by comparison of the values in Table 3 with those for the influent water in Table 1. All values, with the exception of the dissolved oxygen which is expressed in Table 3 as per cent oxygen consumed, are in the same units and directly comparable. These dissolved oxygen figures were obtained from oxygen determinations on samples taken on the same day at the inlet and outlet of each unit. The value is useful as an indication of the corroding tendency of a material, since nearly all normal corrosion processes use oxygen in direct proportion to the amount of corrosion occurring. Although the actual amount of oxygen consumed, or utilized, by the specimen is a criterion of the amount of corrosion, the amount, expressed as percentage consumed, gives values which are more readily comparable since obviously more oxygen will be consumed from water high in oxygen content than from water low in oxygen content. This value should not be confused, however, with the same term as used in sewage treatment.

The iron content of the effluent is another useful analytical value to indicate the relative corrosion of ferrous piping or the efficacy of

TABLE 2

Identification of Specimens

SPEC. NO.	MANUFACTURER	MATERIAL		LINING			DURATION OF TEST
		Trade name	Type	Trade name	Type	Thickness	
			SIX-INCH PIPE				
						in.	mo.
1*	Lock-Joint Pipe Co.	Lock-Joint	Concrete Pipe-Steel Cylinder Reinforced	None	None		27
2	Amer. Rolling Mill Co.	Armco.	Spiral Welded Ingot Iron Pipe	Wales-Dove Hermiston *70B	Spun Bitumastic Lining	1/16	27
3	Amer. Cast Iron Pipe Co.	Mono-Cast	Centrifugal Cast Iron—Cast in Sand Mold	Enameline	Thin Cement Lining With Asphalt Seal Coat	1/16	18½
4	"	"	"		Thin Cement Lining Treated With Sodium Silicate	1/16	27
5	"	"	"	Barrett Co.	Spun Bituminous Enamel Lining	1/16	27
6	Unknown		Pit Cast Iron—In Service 30 Years		Originally Tar Dip—Practically No Lining During Test		31
7	National Tube Co.		Steel Pipe		Heavy Galvanized		31½
8	"	National Black Duroline Pipe	Steel Pipe	Duroline	Heavy Cement Lining	1/8	31½
9	"		Steel Pipe	National Bitumastic Dip	Bituminous Dip Lining		29½
10	Johns Manville Co.	Transite	Cement Asbestos Pipe	None	None		31
11	National Cast Iron Pipe Co.	Super de Lavaud	Centrifugal Cast Iron—Cast In Metal Molds		Standard Cement Lining	1/4	31½
12	U. S. Cast Iron Pipe Co.	"	"		Tar Dip Lining		32
13	"	"	"		Cement Lining Tar Seal Coat	1/4	32
14	Mueller Brass Co.	Streamline	K-Copper Pipe	None	None		32
15	Keasley Mattison Co.	Century Duralite	Cement Asbestos Pipe	None	None		6½
16	Youngstown Sheet & Tube Co.		Steel Pipe	Hill-Hubbell	Heavy Pitch Lining	1/4	28
17	Same as No. 6						31
30	Aluminum Co. of America	38 Alloy	Aluminum Alloy Pipe	None	None		12
31	"	Alclad	"	None	None		12½
32	U. S. Cast Iron Pipe Co.	Super de Lavaud	Centrifugal Cast Iron—Cast In Metal Molds	Enameline	Thin Cement Lining Seal Coating	1/16	13½
33	"	"	"	Wales-Dove Hermiston	Spun Bitumastic Enamel Lining	1/16	13½

* This specimen had a nominal diameter of 8 inches.

TABLE 2—*Concluded*

SPEC. NO.	MANUFACTURER	MATERIAL		LINING		Thickness	DURATION OF TEST
		Trade name	Type	Trade name	Type		
			SIX-INCH PIPE—*Continued*			in.	mo.
34	Amer. Cast Iron Pipe Co.	Mono-Cast	Centrifugal Cast Iron—Cast In Sand Molds		Thin Cement Lining Spec. Sulfate Res.	1/16	5½
35	"	"	"	Enameline	Thin Cement Lining With Asphalt Seal Coat	1/16	5½
36	Amer. Cast Iron Pipe Co.	Mono-Cast	Centrifugal Cast Iron—Cast In Sand Molds		Std. Portland Cement Lining	1/16	5½
37	"	"	"	Enameline	Thin Cement Lining With Asphalt Seal Coat	1/16	5½
38	Amer. Cast Iron Pipe Co.	Mono-Cast	Centrifugal Cast Iron—Cast In Sand Molds		High Alumina Cement Lining	1/16	5½
39	"	"	"		Modified Portland Cement Lining	1/16 3/32	4½ 4½
40	Unknown		Old Cast Iron Cleaned	Tate	Cement Lined In Place	1/8	5½
41	Amer. Rolling Mill. Co.	Armco.	Spiral Welded Ingot Iron Pipe	Wales - Dove Hermiston #70B	Spun Bitumastic Lining	1/16	24†
42	Johns Manville Co.	Transite	Cement Asbestos Pipe	None	None		1½
49	National Cast Iron Pipe Co.	Super de Lavaud	Centrifugal Cast Iron—Cast in Metal Molds	Thin	Cement Lining with Asphalt Seal Coat	1/16	2½
50	National Cast Iron Pipe Co.	Super de Lavaud	Centrifugal Cast Iron—Cast in Metal Molds		Std. Cement Lining	1/8	2½
			THREE-QUARTER-INCH PIPE				
18	Mueller Brass Co.	Streamline	K-Copper Pipe	None	None		26½
19	Anaconda Copper Co.	Anaconda 67	Yellow Brass Pipe	None	None		26½
20	National Tube Co.	Duroline	Galvanized Steel Tubing	Duroline	Std. Galvanized & Cement Lining	1/16	26½
21	Jones-Laughlin Steel Co.		Black Steel Tubing	None	None		26½
22	Youngstown Sheet & Tube Co.		Galvanized Steel Tubing		Std. Galvanized		27
23	A. M. Byers	Byers' Genuine W. I. Galvanized Pipe	Galvanized Wrought Iron Pipe		"		25½
24	Youngstown Sheet & Tube Co.	Youngstown Copper Old Galv. Tubing	Galv. Copper Bearing Steel Tubing		Std. Galvanized		21½

† Not continuous.

FIG. 2A. Staining of Plates in 6-Inch Pipe Tests

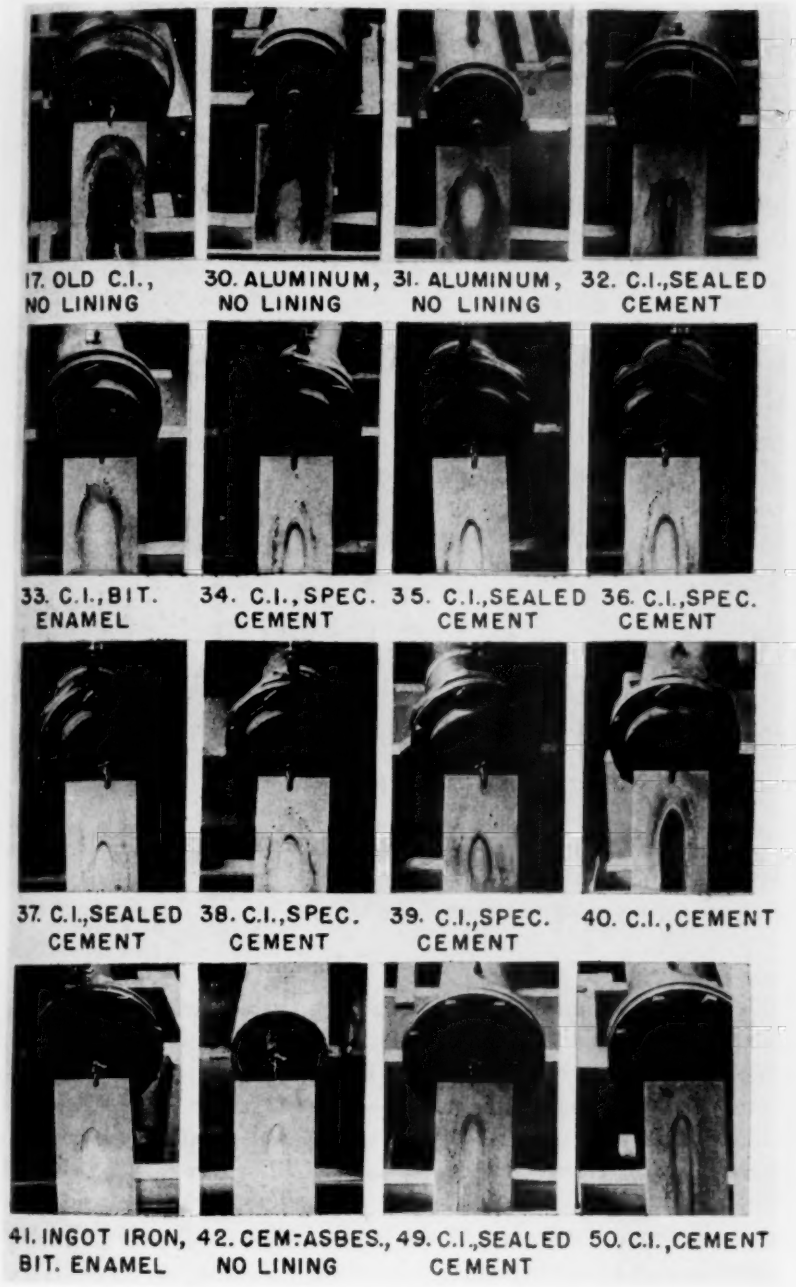

17. OLD C.I., NO LINING
30. ALUMINUM, NO LINING
31. ALUMINUM, NO LINING
32. C.I., SEALED CEMENT
33. C.I., BIT. ENAMEL
34. C.I., SPEC. CEMENT
35. C.I., SEALED CEMENT
36. C.I., SPEC. CEMENT
37. C.I., SEALED CEMENT
38. C.I., SPEC. CEMENT
39. C.I., SPEC. CEMENT
40. C.I., CEMENT
41. INGOT IRON, BIT. ENAMEL
42. CEM:ASBES., NO LINING
49. C.I., SEALED CEMENT
50. C.I., CEMENT

FIG. 2B. Staining of Plates in 6-Inch Pipe Tests

a lining on ferrous pipe. Certainly this is the best analytical value to indicate tendency of pipe to cause red water staining. Comparison of iron content values in Table 3 with the staining shown in Figs. 2 and 3 show that as little as 0.05 p.p.m. Fe is sufficient to cause some red stain on the porcelain plates. In some cases high iron content of water from non-ferrous or heavily lined ferrous pipe is undoubtedly caused by lack of protection of iron caps used in assembling the units, or by exposed bare metal at the taps.

Turbidity and color results afford other valuable data on the tendency of various pipe materials and linings to affect water quality.

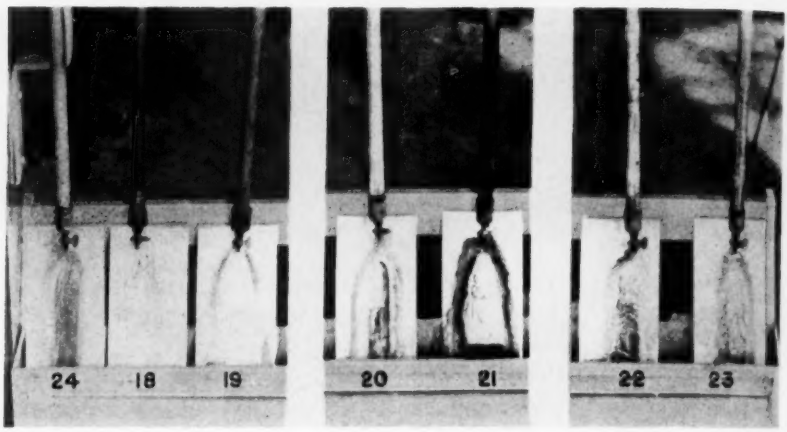


FIG. 3. Staining of Plates in ¾-Inch Pipe Tests

For cementitious pipe, the degree of attack on the cement is best evaluated by consideration of the pH, hardness, and alkalinity increases during passage through the section.

Analysis of Data

Although the best method of studying the analytical values is by comparing values in Table 3 with the pristine values in Table 1, Figs. 4 to 10 show the trends of various types of materials and the comparative ratings as to certain selected values. Figure 4 gives the effect of time of contact (reciprocal of rate of flow) on iron content of water from the two 30-year-old 6-inch cast iron sections. Figure 5 gives the iron content of water from four cast iron pipe units, showing the comparative protection given by various types of linings.

Unless protected by a seal coat, cement-lined pipe tends to increase the hardness of the water. Figure 6 shows the hardness of water from two similar cement-lined specimens. One specimen, however, was protected by a tar seal coat. In Figure 7 is shown the effect of three other cementitious specimens on water hardness.

The reduction in oxygen content of water, by passage through a pipe, is a useful measure of the corroding tendency of the pipe. Figure 8 shows the rating of all test specimens which have been in the test over one year, according to the per cent oxygen consumed.

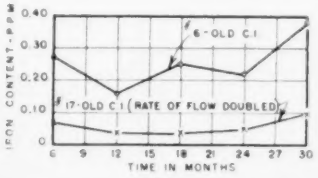


FIG. 4

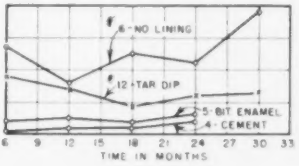


FIG. 5

FIG. 4. Effect of Rate of Flow on Iron Content

FIG. 5. Effect of Different Linings on Iron Content of 6-Inch Cast-Iron Pipe

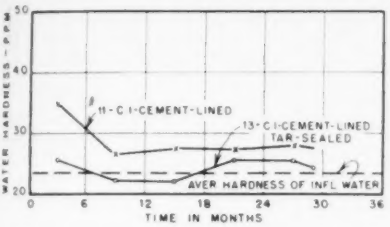


FIG. 6.

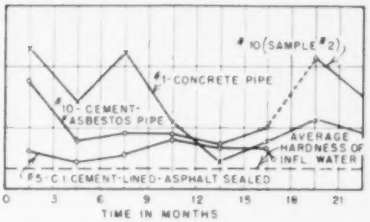

#10 (SAMPLE #2)
#1 - CONCRETE PIPE
#10 - CEMENT-ASBESTOS PIPE
AVERAGE HARDNESS OF INFL. WATER
#5 - C.I. CEMENT-LINED - ASPHALT SEALED
0 3 6 9 12 15 18 21
TIME IN MONTHS

FIG. 7

FIG. 6. Effect of Seal Coating of Cement-Lined Cast-Iron Pipe on Water Hardness

FIG. 7. Effect of Other Cementitious Pipe on Water Hardness

(The apparently anomalous position of Specimen No. 13, which would be expected to be on the low side, is believed to be due to the fact that the iron caps were unprotected.)

Figure 9 shows the comparative ratings of the 6-inch ferrous specimens and all the $\frac{3}{4}$-inch specimens regarding average iron content of the water from the specimens. Note also how the linings reduce the iron pick-up of the water.

In Figure 10 is shown the rating of the cementitious pipe specimens as to their effect on increasing the water hardness. The first month average is given together with the fourth month average, and where

possible, the tenth month average. This figure indicates the intensity and the persistence of the leaching of various cement products by the water.

Results of these laboratory tests have been correlated with data on pipe in service for several of the types of pipe in test. About 50 miles of varied pipe installations in Atlanta and neighboring cities constitute a series of field tests used to supplement the laboratory data. Water analyses at influent and effluent of these field test lines are periodically made as are the laboratory tests on the smaller specimens. This type of correlation has definitely shown that the

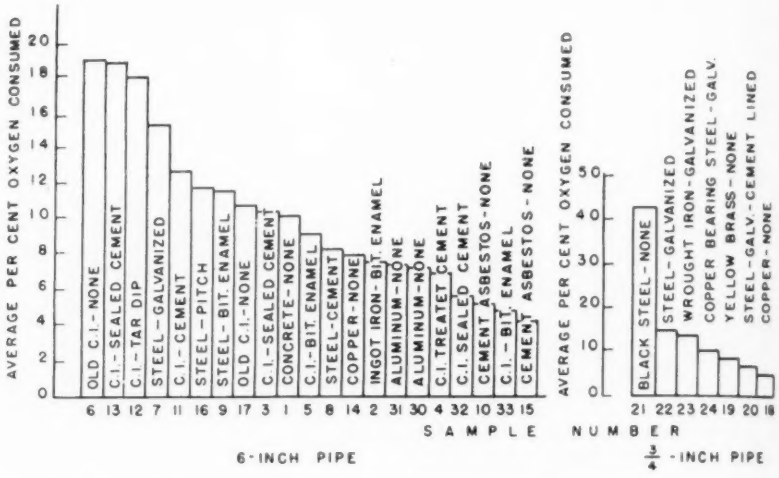


FIG. 8. Effect of Type of Pipe on Oxygen Consumed; all pipe in test for more than one year

laboratory data in every case correctly indicate at least the trend of effect on water quality to be expected from a given type of pipe material or lining. Table 4 shows the agreement in effect on pH of water between a few field tests and the corresponding laboratory tests for the same period.

Conclusions

Conclusions drawn from these tests apply only to the units tested and to the particular water used in the tests. The results may, however, give some indication of how the various pipe materials will serve in a distribution system of this or any similar water. Follow-

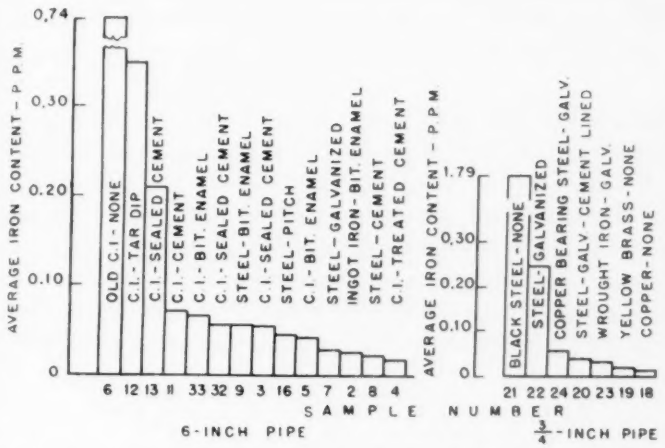


FIG. 9. Effect of Type of Pipe on Iron Content; all pipe in test for more than one year

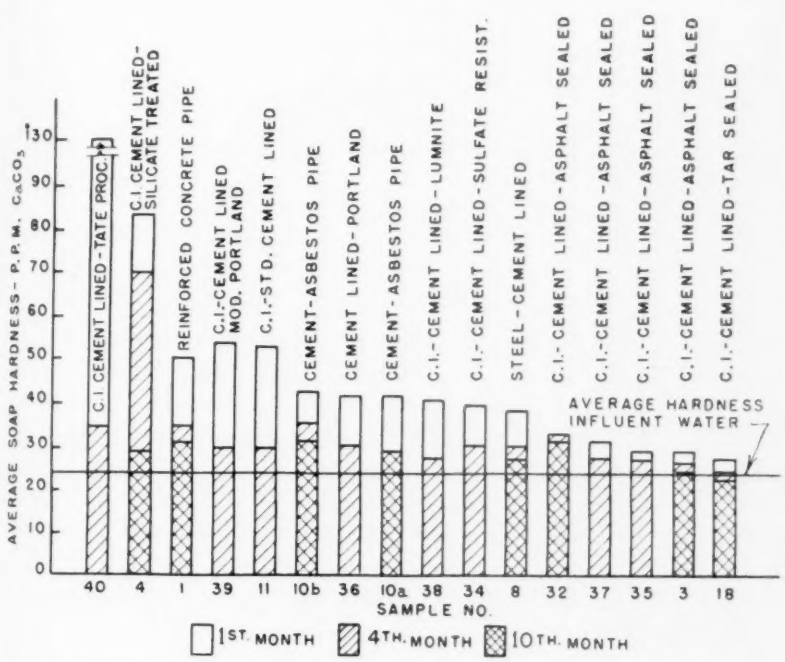

AVERAGE SOAP HARDNESS - P.P.M. CaCO3
130
90
80
70
60
50
40
30
20
10
0
C.I. CEMENT LINED - TATE PROC.
C.I. CEMENT LINED - SILICATE TREATED
REINFORCED CONCRETE PIPE
C.I. - CEMENT LINED MOD. PORTLAND
C.I. - STD. CEMENT LINED
CEMENT - ASBESTOS PIPE
CEMENT LINED - PORTLAND
CEMENT - ASBESTOS PIPE
C.I. - CEMENT LINED - LUMNITE
C.I. - CEMENT LINED - SULFATE RESIST.
STEEL - CEMENT LINED
C.I. - CEMENT LINED - ASPHALT SEALED
C.I. - CEMENT LINED - ASPHALT SEALED
C.I. - CEMENT LINED - ASPHALT SEALED
C.I. - CEMENT LINED - ASPHALT SEALED
C.I. - CEMENT LINED - TAR SEALED
AVERAGE HARDNESS INFLUENT WATER
40 4 1 39 11 10b 36 10a 38 34 8 32 37 35 3 18
SAMPLE NO.
1ST. MONTH
4TH. MONTH
10TH. MONTH

FIG. 10. Effect of Cementitious or Cement-Lined 6-Inch Pipe on Water Hardness

ing are the tentative conclusions which are indicated by the results available at present on 48 test units representing 30 different products:

(1) Bare or unlined ferrous pipe shows internal corrosion by Atlanta water, sufficient to cause tuberculation and staining where the rate of flow is low.

(2) All linings tested serve to reduce the internal corrosion, although the ordinary tar-dip lining gave little protection.

(3) Cementitious pipe in most cases shows markedly less staining, but the hardness, alkalinity, and pH of the water are increased unless the cement is protected by seal coating. Recently developed low

TABLE 4

Correlation with Field Tests

TESTS COMPARED	AVE. pH CHANGE OF WATER
2 miles of 6″ Enameline pipe	+0.2
Test Unit No. 3	+0.2
5 miles of old 12″ cast-iron pipe	−0.5
Test Unit No. 6	−0.4
2 miles of 6″ Transite pipe	+0.7
Test Unit No. 10	+0.6
10 miles of 24″ Bitumastic-Lined steel pipe	−0.4
Test Unit No. 2	−0.5

soluble cement is rapidly gaining favor as a protective coating for cast iron and steel pipe.

(4) Bituminous enamel or pitch linings do not cause increase in hardness and alkalinity and, when carefully made, reduce the tendency of the water to stain.

(5) Galvanizing, particularly of service pipe, is of considerable value in preventing iron corrosion of the pipe, at least for the duration of these tests.

(6) Non-ferrous metallic pipe, such as copper, brass, and aluminum alloys show little or no attack by this water.

(7) The average mile of distribution piping, at Atlanta, has an inventory value of about $10,000. New mains in the aggressive

water districts in the U. S. cost about $14,000,000 annually. Intelligent purchasing of all Atlanta's distribution piping is the direct result of these controlled tests.

This work is being carried on at the Atlanta Water Purification Plants under the inspiration and counsel of W. Z. Smith, General Manager. Sincere appreciation is expressed to all pipe manufacturing plant collaborators and others who have furnished material and suggestions for this work.

References

1. Langelier, W. F. The Analytical Control of Anti-Corrosion Water Treatment. Jour. A. W. W. A. **28:** 1500 (1936).
2. Baylis, J. R. Prevention of Corrosion and Red Water. Jour. A. W. W. A. **15:** 598 (1926).
3. Wiggin, T. H. Engineering and Economic Aspects of Pipe Corrosion and its Control. Jour. A. W. W. A. **30:** 1343 (1938).
4. Norcom, George D. Outline of the Corrosion Problem in Water Works. Jour. A. W. W. A. **32:** 401 (1940).
5. Hoover, Charles P. The Corrosive Action of Various Types of Water on Household Plumbing. W. W. and Sewerage **83:** 384 (1936).
6. Hale, Frank E. Experiments in Pipe Corrosion. W. W. Eng. **87:** 710 (1934).
7. Donoho, Chas. K. Description of 6-Inch Main Test Units Used in Research Laboratory of American Cast Iron Pipe Co. Correspondence, 1939.
8. Smith, W. Z. and Weir, Paul. Progress Report No. 1, Tests at Atlanta Water Works.

Table 3 begins on the following page

TABLE 3

Analytical Data on Test Units

DATE	TIME IN TEST	AVE. NO. OF TESTS	TEMP. °F.	TURBIDITY	COLOR	HARDNESS	CARBON DIOXIDE	pH	Fe	% OXYGEN CONS.	DISSOLVED SOLIDS	RES. CHLORAMINE	ALKALINITY M.O.	ALKALINITY Phen.
Unit No. 1—8-inch Reinforced-Concrete—Test Started Oct. 16, 1937														
1937														
Oct. 16		1	70	0.75	5.0	49.6	0.0	10.5	9.4				49.5	
Oct. 23	7 days	1	62	0.5	5.0	48.0	0.0	10.3	0.02				42.3	
Oct. 30	14 "	1	60		5.0	68.0	0.0	10.5	0.02				46.5	
Nov.	1 mo.	4	53.5	0.5	5.0	42.8	0.0	10.1	0.01				35.3	
Dec.	2½ "	1	50	0.5	5.0	38.0	0.0	9.3	Trace				21.5	
1938														
Jan.-Feb.-Mar.	4 "	5	51	0.5	5.0	34.5	0.0	9.4	"				25.3	12.8
Apr.-May-June	7 "	3	69	0.55	5.8	39.4	0.0	9.7	0.01			0.0	30.3	16.5
July-Aug.-Sept.	10 "	3	77	0.4	5.0	30.7	0.0	9.3	0.02	20		0.05	25.0	11.0
Oct.-Nov.-Dec.	13 "	2	49	0.2	5.0	24.6	0.0	8.9	0.02	11		0.15	22.0	6.2
1939														
Jan.-Feb.-Mar.	16 "	3	50.5	0.4	5.0	27.9	0.0	9.3	0.02	17		0.08	21.8	8.6
Apr.-May-June	19 "	6	59.0	0.35	5.0	31.9	0.0	9.7	0.02	8		Trace	21.4	13.3
July-Aug.-Sept.	23 "	4	81.5	0.7	5.0	28.8	0.0	9.0	0.04	8		0.13	23.6	7.2
Oct.-Nov.-Dec.	26 "	3	64	0.55	5.0	29.3	0.0	9.1	0.03	8	40.0	0.15	22.8	8.2
1940														
Jan.-Feb.	28 "	2	52.5	0.45	5.0	28.5	0.0	9.0	0.03	0	35.0	0.18	21.0	7.0
Unit No. 2—6-inch Welded-Steel, Bituminous-Lined—Test Started Oct. 16, 1937														
1937														
Oct. 16		1	70	0.5	5.0	22.0	0.0	8.3	0.01				15.0	
Oct. 23	7 days	1	62	0.4	5.0	24.0	0.0	8.0	0.01				14.0	
Oct. 30	14 "	1	60		5.0	23.0	0.5	7.7	0.01				13.5	
Nov.	1 mo.	4	52.5	0.45	5.0	22.2	0.25	7.95	Trace				14.3	
Dec.	2½ "	1	50	0.4	5.0	20.0	0.0	8.1	0.02				14.0	
1938														
Jan.-Feb.-Mar.	4 "	5	51	1.1	5.0	21.1	0.5	8.0	Trace				14.7	0.0
Apr.-May-June	7 "	3	70	0.4	5.0	23.0	0.3	7.7	0.02			Trace	14.5	0.8
July-Aug.-Sept.	10 "	3	77	0.3	5.0	23.5	0.16	7.8	0.02	19		0.16	14.1	0.5
Oct.-Nov.-Dec.	13 "	2	49	0.3	5.0	24.0	0.0	8.1	0.02	8		0.15	16.0	1.3
1939														
Jan.-Feb.-Mar.	16 "	3	50.5	0.4	5.0	22.3	0.0	7.4	0.02	3		0.08	8.3	0.5
Apr.-May-June	19 "	6	73.5	0.35	5.0	23.6	0.75	7.64	0.03	9		Trace	14.35	0.0
July-Aug.-Sept.	23 "	4	81.5	0.5	5.0	24.0	0.0	8.0	0.03	9		0.15	15.4	1.3
Oct.-Nov.-Dec.	26 "	3	65.5	0.5	5.0	24.6	0.5	7.85	0.03	5	32.0	0.18	16.5	0.5
1940														
Jan.-Feb.	28 "	2	52.5	0.4	5.0	24.5	0.0	8.00	0.03	0	28.0	0.15	15.25	0.8
Unit No. 3—6-inch Cast-Iron, Thin Cement Lining Asphalt-Sealed—Test Started July 26, 1938														
1938														
July 26	1 day	1	81	0.4	5.0	29.0	0.0	9.1	0.01	18		Trace	19.8	7.3
Aug. 29	33 days	1	83	0.03	5.0	25.0	0.0	8.8	0.02	18		"	17.8	4.7
Sept. 22	56 "	1	68	0.4	5.0	25.0	0.0	8.7	0.02	18		0.05	18.0	4.0
Oct.-Nov.-Dec.	4 mo.	3	49	0.1	5.0	24.4	0.0	8.5	0.02	9		0.15	17.5	2.5
1939														
Jan.-Feb.-Mar.	7 "	3	50.5	0.5	5.0	25.6	0.0	8.6	0.02			0.10	15.3	3.0
Apr.-May-June	10 "	3	72.5	0.56	5.0	28.5	0.0	8.7	0.06	6		0.08	18.6	4.0
July-Aug.-Sept.	13 "	2	82.0	1.25	5.0	26.8	0.0	8.6	0.10	7		0.15	18.3	3.3
Oct.-Nov.-Dec.	16 "	3	65.0	0.75	5.0	25.5	0.0	8.4	0.08	8	32.7	0.15	17.5	2.5
1940														
Jan.-Feb.	19 "	2	52.5	0.45	5.0	26.5	0.0	8.5	0.08	0	30.0	0.15	16.5	2.8

TABLE 3—*Continued*

DATE	TIME IN TEST	AVE. NO. OF TESTS	TEMP. °F.	TURBIDITY	COLOR	HARDNESS	CARBON DIOXIDE	pH	Fe	% OXYGEN CONS.	DISSOLVED SOLIDS	RES. CHLORAMINE	ALKALINITY M.O.	ALKALINITY Phen.
Unit No. 4—6-inch Cast-Iron, Thin Cement Lining Silicate-Treated—Test Started Oct. 16, 1937														
1937														
Oct. 16		1	70	0.5	5.0	68.8	0.0	10.7	0.01				69.5	
Oct. 23	7 days	1	62	0.4	5.0	72.0	0.0	10.7	0.03				62.5	
Oct. 30	14 "	1	60		5.0	120.0	0.0	10.9	0.02				78.7	
Nov.	1 mo.	4	53.5	0.51	5.0	68.5	0.0	10.2	Trace				43.8	
Dec.	2½ "	1	50	0.5	5.0	49.2	0.0	10.0	0.01				36.8	
1938														
Jan.-Feb.-Mar.	4 "	5	51	0.55	5.0	71.9	0.0	10.4	0.01				49.4	27.0
Apr.-May-June	7 "	3	70	0.55	5.7	35.5	0.0	9.5	0.03			0.05	24.4	13.4
July-Aug.-Sept.	10 "	3	77	0.03	5.0	28.1	0.0	9.1	0.02	17		0.05	21.2	8.0
Oct.-Nov.-Dec.	13 "	2	49	0.1	5.0	25.2	0.0	8.6	0.01			0.20	17.5	3.0
1939														
Jan.-Feb.-Mar.	16 "	3	50.5	0.5	5.0	25.3	0.0	8.7	0.01			0.13	16.5	3.9
Apr.-May-June	19 "	6	73.5	0.33	5.0	29.0	0.0	8.9	0.03	5		0.08	19.9	6.0
July-Aug.-Sept.	22 "	4	81.5	0.45	5.0	27.5	0.0	8.8	0.03	7		0.13	19.5	4.8
Oct.-Nov.-Dec.	25 "	3	65.5	0.55	5.0	29.0	0.0	8.8	0.05	8	35.0	0.13	18.5	5.0
1940														
Jan.-Feb.	28½ "	2	52.5	0.45	5.0	28.0	0.0	8.7	0.04	0	32.0	0.15	18.0	4.5
Unit No. 5—6-inch Cast-Iron, Bituminous-Lined—Test Started Oct. 15, 1937														
1937														
Oct. 15		1	70	0.75	12.0	23.0	0.0	8.3	0.12				15.5	
Oct. 23	8 days	1	62	0.5	5.0	22.8	0.0	8.2	0.03				14.0	
Oct. 29	14 "	1	60	0.5	5.0	24.4	0.5	7.8	0.05				14.3	
Nov.	1½ mo.	4	54	0.75	6.0	21.5	0.75	7.5	0.07				14.6	
Dec.	2½ "	1	50	0.5	5.0	20.6	0.0	8.2	0.03				14.8	
1938														
Jan.-Feb.-Mar.	4 mo.	5	51	1.1	5.0	20.7	0.3	7.9	0.03				14.8	0.0
Apr.-May-June	7 "	3	69	0.52	6.3	22.6	0.8	7.6	0.04			Trace	14.1	0.0
July-Aug.-Sept.	10 "	3	77	0.48	5.0	23.5	0.5	7.7	0.05	25		"	13.9	0.3
Oct.-Nov.-Dec.	13 "	1	49	0.3	5.0	23.0	0.5	7.6	0.03	5		0.20	16.0	0.0
1939														
Jan.-Feb.-Mar.	16 "	3	50.5	0.46	5.0	22.7	0.3	7.8	0.04			0.08	12.8	1.66
Apr.-May-June	19½ "	6	76.0	0.36	5.0	22.7	0.5	7.8	0.04	10		0.10	14.3	0.0
July-Aug.-Sept.	22½ "	4	81.5	0.75	5.0	22.4	0.3	7.9	0.07	7		0.08	14.8	0.8
Oct.-Nov.-Dec.	25½ "	3	65.5	0.53	5.0	24.0	0.5	7.8	0.05	8	32.7	0.15	15.8	0.8
1940														
Jan.-Feb.	28½ "	2	52.5	0.4	5.0	24.5	0.0	8.1	0.06	0	28.0	0.15	14.8	0.8
Unit No. 6—6-inch Cast-Iron, 30 Years Old—Test Started May 18, 1937														
1937														
May 24	6 days	1	75	20.0	70	31.0	16.0	6.1	9.4				7.8	
June	1½ mo.	5	82.3	17.0	112	22.8	7.8	6.5	4.17				10.6	
July	2 "	4	82	14.0	80	24.3	4.2	6.8	1.06				13.3	
Aug.-Sept.	3½ "	5	82	5.0	50	23.5	2.4	7.0	0.39				13.7	
Oct.-Nov.-Dec.	6 "	9	59	2.4	19	21.8	0.8	7.5	0.26				15.1	
1938														
Jan.-Feb.-Mar.	9 "	5	51	1.8	22	20.5	0.2	8.0	0.22				14.8	0.5
Apr.-May-June	12 "	3	70	1.3	24	22.3	0.3	7.8	0.15			Trace	14.9	0.3
July-Aug.-Sept.	15 "	3	77	3.0	42	23.5	0.3	7.9	0.32	37		"	16.2	0.5
Oct.-Nov.-Dec.	18 "	1	49	0.5	15	23.0	0.0	8.1	0.15	19		0.15	16.2	1.0

TABLE 3—*Continued*

DATE	TIME IN TEST	AVE. NO. OF TESTS	TEMP. °F.	TURBIDITY	COLOR	HARDNESS	CARBON DIOXIDE	pH	Fe	% OXYGEN CONS.	DISSOLVED SOLIDS	RES. CHLORAMINE	ALKALINITY M.O.	ALKALINITY Phen.
Unit No. 6—6-inch Cast-Iron, 30 Years Old—Test Standard May 18, 1937—*Continued*														
1939														
Jan.-Feb.-Mar...	21 mo.	3	51	2.5	20	22.7	0.0	8.3	0.18	17		0.10	13.2	1.3
Apr.-May-June .	24 "	3	70	1.3	24	22.3	0.3	7.8	0.19	23		Trace	14.9	0.3
July-Aug.-Sept..	27½ "	4	81	2.5	11	24.8	0.0	8.2	0.27	22		0.10	15.6	1.5
Oct.-Nov.-Dec.	30½ "	3	67	3.0	25	25.0	0.0	8.0	0.43	24	32.0	0.06	17.5	1.0
1940														
Jan.-Feb.....	33½ "	2	53	0.8	14	25.0	0.0	8.4	0.34	12	29.0	0.13	16.3	1.8
Unit No. 7—6-inch Steel, Galvanized—Test Started May 26, 1937														
1937														
June 1.....	6 days	1	80	5.0	50.0	24.0	0.0	8.5	0.04				19.0	
June 8.....	13 "	1	81	10.0	50.0	26.0	0.0	8.5	0.03				19.5	
June 16.....	20 "	1	82	8.0	35.0	24.8	0.0	8.5	0.03				19.0	
June 23.....	27 "	1	83	3.0	25.0	24.0	0.0	8.4	0.03				17.8	
June 30.....	34 "	1	83	3.0	15.0	24.0	0.0	8.3	0.03				15.8	
July.....	2 mo.	4	82	4.8	21.3	25.2	0.0	8.3	0.03				16.4	
Aug.....	3 "	4	83	4.8	24.3	26.0	0.0	8.3	0.02				16.5	
Sept.....	4 "	1	80	3.0	18.0	25.6	0.0	8.2	0.02				17.5	
Oct.-Nov.-Dec.	5½ "	9	59.6	3.9	15.2	22.7	0.05	8.3	Trace				16.5	
1938														
Jan.-Feb.-Mar...	8½ "	5	51	5.0	20.4	21.6	0.0	8.3	"				17.9	
Apr.-May-June .	11½ "	3	69.6	6.5	29.0	23.8	0.0	8.2	0.01			0.05	17.5	1.5
July-Aug.-Sept.	14½ "	3	77.3	4.6	21.6	23.3	0.05	8.0	0.02	28		0.05	15.9	0.9
Oct.-Nov.-Dec.	17½ "	2	49	2.0	10.0	22.6	0.5	7.8	0.03	17		0.20	16.3	0.0
1939														
Jan.-Feb.-Mar...	20½ "	3	50.5	11.3	28.3	23.1	0.0	8.1	0.07			0.05	16.5	0.9
Apr.-May-June.	23½ "	3	73.6	3.6	15.7	24.0	0.0	8.1	0.03	13		0.05	17.4	1.2
July-Aug.-Sept..	26½ "	2	81.0	5.0	10.0	23.5	0.0	8.0	0.03	11		0.10	17.3	0.5
Oct.-Nov.-Dec..	29½ "	3	67.0	3.7	14.6	24.6	0.2	8.0	0.06	12	33.0	0.10	18.0	0.8
1940														
Jan.-Feb.-Mar...	32½ "	2	54.5	1.5	12.0	24.5	0.2	7.9	0.19	1	31.0	0.15	16.3	0.3
Unit No. 8—6-inch Steel, Cement-Lined—Test Started May 26, 1937														
1937														
June 1.....	6 days	1	80	0.4	5.0	73.0	0.0	10.5	0.04				53.8	
June 8.....	13 "	1	81	0.5	5.0	44.8	0.0	10.3	0.03				38.5	
June 16.....	20 "	1	82	0.5	5.0	42.0	0.0	10.0	0.03				34.0	
June 23.....	27 "	1	83	0.4	5.0	32.6	0.0	9.3	0.03				24.0	
June 30.....	34 "	1	83	0.3	5.0	33.0	0.0	9.3	0.03				23.0	
July.....	2 mo.	4	82.3	0.3	5.0	33.1	0.0	9.1	0.03				22.1	
Aug.....	2½ "	4	82.5	0.55	5.0	32.1	0.0	8.9	0.02				19.5	
Sept.....	3 "	1	80	0.75	5.0	31.6	0.0	8.9	0.02				18.0	
Oct.-Nov.-Dec.	5½ "	9	59.6	0.5	5.0	26.7	0.0	8.8	0.01				19.8	
1938														
Jan.-Feb.-Mar..	8½ "	5	51	0.5	5.0	25.6	0.0	8.7	0.01				18.5	4.5
Apr.-May-June .	11½ "	3	70	0.6	5.0	28.9	0.0	8.9	0.03			Trace	20.0	6.2
July-Aug.-Sept.	14½ "	3	77	0.3	5.0	27.5	0.0	8.8	0.03	17		0.05	19.3	5.3
Oct.-Nov.-Dec..	17½ "	1	49	0.3	5.0	24.0	0.0	8.5	0.01	7.5		0.20	17.0	3.0

TABLE 3—*Continued*

DATE	TIME IN TEST	AVE. NO. OF TESTS	TEMP. °F.	TURBIDITY	COLOR	HARDNESS	CARBON DIOXIDE	pH	Fe	% OXYGEN CONS.	DISSOLVED SOLIDS	RES. CHLORAMINE	ALKALINITY M.O.	ALKALINITY Phen.
Unit No. 8—6-inch Steel, Cement-Lined—Test Started May 26, 1937—*Continued*														
1939														
Jan.-Feb.-Mar.	20½ mo.	3	50.5	0.55	5.0	26.1	0.0	9.0	0.03			0.05	19.5	5.7
Apr.-May-June.	23½ "	3	74.0	0.3	5.0	27.3	0.0	8.8	0.035	8		0.08	19.3	5.3
July-Aug.-Sept.	26½ "	2	81.0	0.5	5.0	26.7	0.0	8.8	0.04	7		0.13	19.8	4.6
Oct.-Nov.-Dec.	29½ "	3	67.0	0.6	5.0	29.0	0.0	8.7	0.04	10	37.0	0.12	19.7	4.3
1940														
Jan.-Feb.	32 "	2	56.5	0.4	5.0	27.5	0.0	8.5	0.0	1	34.0	0.15	18.8	3.5
Unit No. 9—6-inch Steel, Bituminous-Lined—Test Started May 26, 1937														
1937														
June 1	6 days	1	80	0.4	5.0	22.0	0.0	8.4	0.06				14.0	
June 8	13 "	1	81	0.4	5.0	22.0	1.0	7.7	0.09				13.5	
June 16	20 "	1	82	0.5	5.0	22.0	1.5	7.5	0.10				14.5	
June 23	27 "	1	83	0.4	5.0	24.0	0.0	8.2	0.07				13.5	
June 30	34 "	1	83	0.4	5.0	24.0	1.0	7.9	0.10				13.2	
July-Aug.-Sept.	2½ mo.	9	82	0.5	5.0	23.8	0.3	8.1	0.06				13.6	
Oct.-Nov.-Dec.	3½ "	9	59	0.5	5.0	21.8	0.5	7.9	0.03				14.7	
1938														
Jan.-Feb.-Mar.	6½ "	5	51	0.5	5.0	21.1	0.1	8.0	0.02				14.6	
Apr.-May-June.	9½ "	3	70	0.55	5.0	22.9	0.5	7.7	0.05			Trace	14.2	0.7
July-Aug.-Sept.	12½ "	3	77	0.4	5.0	23.4	0.3	7.9	0.06	21		0.02	14.3	0.3
Oct.-Nov.-Dec.	15½ "	1	49	0.3	5.0	22.0	0.5	7.6	0.03	13		0.15	15.0	0.0
1939														
Jan.-Feb.-Mar.	18½ "	3	50.5	0.7	6.6	23.1	0.5	7.7	0.08			0.03	12.2	0.0
Apr.-May-June.	21½ "	3	73.8	0.3	5.0	22.8	0.3	7.8	0.056	12		0.08	14.3	0.3
July-Aug.-Sept.	24½ "	2	81.0	0.75	5.0	24.0	0.5	7.75	0.06	8		0.08	15.3	0.0
Oct.-Nov.-Dec.	27½ "	3	68.7	0.45	5.0	24.7	0.3	7.83	0.08	15	32.7	0.10	16.5	0.2
1940														
Jan.-Feb.	30 "	2	57.5	0.3	5.0	23.5	1.0	7.6	0.105	0	29.0	0.13	15.3	0.0
Unit No. 10—6-inch Asbestos-Cement—Test Started July 19, 1937														
Sample No. 1														
1937														
July-Aug.-Sept.	2½ mo.	7	82.0	0.97	39.3	44.8	0.0	9.74	0.081				33.5	
Oct.-Nov.-Dec.	4 "	9	59	0.57	5.0	28.2	0.0	9.1	0.04				21.8	
1938														
Jan.-Feb.-Mar.	7 "	5	51	0.7	5.0	28.4	0.0	9.14	0.044				21.5	
Apr.-May-June.	10 "	3	70	0.75	5.7	28.7	0.0	8.93	0.043				20.1	6.8
July-Aug.-Sept.	13 "	3	77	0.3	5.0	27.3	0.0	8.83	0.017	17		0.03	19.5	5.7
Oct.-Nov.-Dec.	17 "	1	49	0.3	5.0	29.0	0.0	8.9	0.02	2				
Sample No. 2														
1939														
Jan.-Feb.-Mar.	20 "	3	50.5	0.5	5.0	41.5	0.0	9.9	0.01	3		0.13	31.9	20.0
Apr.-May-June.	23½ "	3	74.0	0.33	5.0	35.2	0.0	9.4	0.02	0		0.15	26.3	11.9
July-Aug.-Sept.	26½ "	2	81.0	0.5	5.0	34.8	0.0	9.4	0.02	2		0.15	26.2	11.9
Oct.-Nov.	28½ "	2	71.0	0.45	5.0	31.5	0.0	9.2	0.045	2	39.0	0.15	24.3	9.8

TABLE 3—*Continued*

DATE	TIME IN TEST	AVE. NO. OF TESTS	TEMP. °F.	TURBIDITY	COLOR	HARDNESS	CARBON DIOXIDE	pH	Fe	% OXYGEN CONS.	DISSOLVED SOLIDS	RES. CHLORAMINE	ALKALINITY M.O.	ALKALINITY Phen.
Unit No. 10—6-inch Asbestos-Cement—Test Started July 19, 1937—*Continued*														
Sample No. 3														
Dec.	29½ mo.	1	64.0	0.5	5.0	34.0	0.0	9.1	0.04	16	40.0	0.20	25.0	8.0
Jan.–Feb. (1940)	32 "	2	57.5	0.35	5.0	29.0	0.0	9.3	0.02	0	39.0	0.18	24.8	10.5
Unit No. 11—6-inch Cast-Iron Cement-Lined—Test Started May 18, 1937														
1937														
May 24	6 days	1	75	0.4	5.0	50.0	0.0	10.4	0.04				45.0	
June	1 mo.	5	81.5	0.65	9.4	49.6	0.0	10.0	0.10				42.4	
July–Aug.–Sept.	2½ "	9	82	3.1	27.7	34.7	0.0	9.0	0.08				22.3	
Oct.–Nov.–Dec.	5½ "	9	59	0.68	5.3	26.0	0.0	8.7	0.07				18.4	
1938														
Jan.–Feb.–Mar.	8½ "	5	51	0.8	5.0	25.9	0.0	8.8	0.06				18.5	6.5
Apr.–May–June	11½ "	3	70	0.75	7.0	28.1	0.0	8.8	0.04			Trace	20.1	7.1
July–Aug.–Sept.	14½ "	3	77	0.55	6.3	27.5	0.0	8.8	0.04	26		0.05	19.2	4.8
Oct.–Nov.–Dec.	17½ "	1	49	0.3	5.0	25.6	0.0	8.6	0.04	12		0.15	17.8	3.5
1939														
Jan.–Feb.–Mar.	20½ "	3	50.5	1.17	7.3	27.2	0.0	9.1	0.07			0.05	21.2	6.5
Apr.–May–June	23½ "	3	74.5	0.4	5.0	28.9	0.0	8.8	0.06	13		0.07	20.1	4.9
July–Aug.–Sept.	26½ "	2	81.5	0.75	5.0	27.8	0.0	8.9	0.06	12		0.10	20.8	5.3
Oct.–Nov.–Dec.	29½ "	3	68.5	0.58	5.7	28.0	0.0	8.7	0.06	13	35.3	0.17	20.7	4.7
1940														
Jan.–Feb.	32 "	2	57.5	0.35	5.0	27.5	0.0	8.7	0.05	0	33.0	0.15	19.3	4.0
Unit No. 12—6-inch Cast-Iron Tar-Dipped—Test Started May 18, 1937														
1937														
May 24	6 days	1	75	0.5	35.0	25.6	2.0	7.3	0.55				16.0	
June	1 mo.	4	81.5	5.25	87.5	23.1	3.2	7.2	1.33				16.4	
July–Aug.–Sept.	3 "	10	82	4.6	52.5	23.5	2.9	6.9	0.49				13.7	
Oct.–Nov.–Dec.	6 "	9	59	0.94	13.0	22.2	1.5	7.1	0.14				14.9	
1938														
Jan.–Feb.–Mar.	9 "	5	51	0.55	6.4	21.6	0.9	7.4	0.09				14.6	0.0
Apr.–May–June	12 "	3	70	1.3	20.7	21.9	1.7	7.0	0.18			Trace	14.2	0.0
July–Aug.–Sept.	15 "	3	77	1.58	17.3	22.3	2.4	6.9	0.10	39		0.02	14.9	0.0
Oct.–Nov.–Dec.	18 "	1	49	0.4	5.0	22.4	0.5	7.7	0.05	16		0.20	15.2	0.0
1939														
Jan.–Feb.–Mar.	21 "	3	50.5	1.0	10.0	22.3	1.3	7.0	0.11			0.02	10.8	0.0
Apr.–May–June	24½ "	3	74	0.55	5.7	24.6	1.3	7.3	0.13	22		0.06	15.3	0.0
July–Aug.–Sept.	27½ "	2	81.5	0.85	6.0	24.0	1.3	7.3	0.12	12		0.05	14.7	0.0
Oct.–Nov.–Dec.	30½ "	3	68.5	1.33	9.0	24.3	1.0	7.6	0.16	20	30.7	0.10	16.5	0.0
1940														
Jan.–Feb.	33 "	2	56.0	0.4	5.0	23.5	0.8	7.7	0.08	0	29.0	0.13	16.3	0.5
Unit No. 13—6-inch Cast-Iron Cement-Lined, Tar-Sealed—Test Started May 18, 1937														
1937														
May 24	6 days	1	75	0.5	10.0	28.0	0.0	8.8	0.11				22.0	
June	1 mo.	4	81.5	3.63	40.0	26.8	0.0	8.5	0.58				23.0	
July–Aug.–Sept.	3 "	10	82	5.67	49.5	26.5	1.5	7.3	0.46				18.5	
Oct.–Nov.–Dec.	6 "	9	60	0.77	11.2	23.1	0.8	7.5	0.11				16.1	

TABLE 3—*Continued*

DATE	TIME IN TEST	AVE. NO. OF TESTS	TEMP. °F.	TURBIDITY	COLOR	HARDNESS	CARBON DIOXIDE	pH	Fe	% OXYGEN CONS.	DISSOLVED SOLIDS	RES. CHLORAMINE	ALKALINITY M.O.	ALKALINITY Phen.
Unit No. 13—6-inch Cast-Iron Cement-Lined, Tar-Sealed—Test Standard May 18, 1937—*Continued*														
1938														
Jan.-Feb.-Mar.	9 mo.	5	51	1.0	8.0	22.4	0.4	7.8	0.10				16.7	0.0
Apr.-May-June	12 "	3	70	1.08	10.6	22.9	0.7	7.2	0.09				15.9	0.0
July-Aug.-Sept.	15 "	3	77	1.8	21.0	24.9	1.2	7.2	0.08	34		0.0	17.5	0.0
Oct.-Nov.-Dec.	18 "	2	49	1.0	12.0	26.0	0.5	7.9	0.11	16		0.05	17.2	0.0
1939														
Jan.-Feb.-Mar.	21 "	3	50.5	1.0	7.0	24.7	0.0	8.3	0.07	34		0.05	16.6	1.7
Apr.-May-June	24½ "	3	74.4	0.72	7.3	26.5	0.0	8.2	0.31	14		0.067	16.5	1.4
July-Aug.-Sept.	27½ "	2	81.5	1.5	10.0	24.0	0.8	7.7	0.13	12		0.125	15.6	0.0
Oct.-Nov.-Dec.	30½ "	3	64.3	1.16	7.3	26.6	0.3	7.9	0.13	21	32.0	0.066	18.0	0.7
1940														
Jan.-Feb.	33 "	2	56.0	0.35	5.0	24.5	0.0	8.3	0.16	1	31.0	0.125	16.3	1.5
Unit No. 14—6-inch Copper—Test Started May 18, 1937														
1937														
May 24	6 days	1	75	0.4	5.0	23.4	0.0	8.3	0.04				13.8	
June	1 mo.	4	81.5	0.38	5.0	23.6	0.0	8.4	0.03				14.4	
July-Aug.-Sept.	4 "	10	80.9	0.58	5.0	22.8	0.47	8.1	0.02				13.2	
Oct.-Nov.-Dec.	5½ "	9	59	0.46	5.0	22.4	0.3	7.9	Trace				14.5	
1938														
Jan.-Feb.-Mar.	8½ "	5	51	0.46	5.0	22.1	0.0	8.2	"				14.6	
Apr.-May-June	11½ "	3	69.7	0.37	5.0	28.7	0.3	7.86	"			Trace	14.2	0.0
July-Aug.-Sept.	14½ "	3	77.3	0.3	5.0	22.3	0.17	7.9	0.01	28		0.017	14.3	0.8
Oct.-Nov.-Dec.	17½ "	1	49	0.3	5.0	23.6	0.0	8.3	0.01	3		0.20	15.6	1.5
1939														
Jan.-Feb.-Mar.	20½ "	3	50.5	0.43	5.0	22.3	0.3	7.8	0.01	5		0.10	13.6	1.0
Apr.-May-June	23½ "	3	74.4	0.33	5.0	23.1	0.0	8.1	0.02	6		0.116	14.5	1.4
July-Aug.-Sept.	26½ "	2	81.5	0.45	5.0	23.7	0.25	7.9	0.02	1		0.15	15.8	0.5
Oct.-Nov.-Dec.	29½ "	3	67.3	0.32	5.0	24.7	0.0	8.1	0.02	1	32.0	0.167	16.5	1.0
1940														
Jan.-Feb.	32 "	2	56.0	0.35	5.0	24.5	0.0	8.1	0.03	0	29.0	0.175	15.3	1.3
Unit No. 15—6-inch Durolite Century K. M.—Test Started May 24, 1939														
1939														
May 26		1	77.5	3.0	10.0	36.4	0.0	9.9	0.03	4		0.15	33.5	20.6
June 22	30 days	1	81.0	0.0	5.0	37.0	0.0	9.9	0.04	3		0.15	31.3	17.0
Aug. 4	69 "	1	88.5	0.5	5.0	32.8	0.0	9.5	0.02	6		0.15	25.3	13.6
Sept. 27	123 "	1		0.0	5.0	29.0	0.0	9.1	0.02	0		0.20	22.7	8.0
Oct. 10	136 "	1	72.0	0.0	5.0	31.0	0.0	9.3	0.02	0	40.0	0.25	25.0	10.0
Nov. 13	170 "	1	64.0	0.5	5.0	29.0	0.0	8.9	0.04	0	38.0	0.25	22.5	7.5
Dec. 6	193 "	1	63.0	0.0	5.0	30.0	0.0	8.9	0.02	21	36.0	0.25	21.5	6.5
1940														
Jan.-Feb.	9 mo.	2	57.0	0.35	5.0	29.0	0.0	10.0	0.03	0	34.0	0.28	20.8	6.5
Unit No. 16—6-inch Steel, Pitch-Lined—Test Started Aug. 10, 1937														
1937														
Aug. 13	3 days	1	82	0.8	5.0	25.2	0.0	8.3	0.02				13.5	
Aug. 19	10 "	1	83	0.8	5.0	24.0	0.0	8.3	0.03				13.0	
Oct.-Nov.-Dec.	4 mo.	6	56.0	0.44	5.0	23.3	0.0	8.13	0.02				15.4	

TABLE 3—*Continued*

DATE	TIME IN TEST	AVE. NO. OF TESTS	TEMP. °F.	TURBIDITY	COLOR	HARDNESS	CARBON DIOXIDE	pH	Fe	% OXYGEN CONS.	DISSOLVED SOLIDS	RES. CHLORAMINE	ALKALINITY M.O.	ALKALINITY Phen.
Unit No. 16—6-inch Steel, Pitch-Lined—Test Started Aug. 10, 1937—*Continued*														
1938														
Jan.-Feb.-Mar.	6 mo.	4	51	0.45	5.0	21.4	0.1	8.1	0.01				14.7	
Apr.-May-June	9 "	3	70	0.43	5.0	22.1	0.7	7.57	0.03				13.8	0.0
July-Aug.-Sept.	12 "	3	77	0.48	7.0	22.3	1.0	7.3	0.04	17		0.0	14.6	0.0
Oct.-Nov.-Dec.	15 "	1	49	0.3	5.0	23.0	0.5	7.8	0.05	16		0.10	15.0	0.0
1939														
Jan.-Feb.-Mar.	17 "	3	50.5	0.47	5.0	22.5	0.4	7.6	0.037	13		0.03	13.2	0.3
Apr.-May-June	20½ "	3	74.0	0.4	5.0	24.5	0.83	7.5	0.033	13		0.05	13.9	0.0
July-Aug.-Sept.	23½ "	2	81.5	2.7	6.5	23.8	0.75	7.6	0.29	7		0.13	14.3	0.0
Oct.-Nov.-Dec.	26½ "	3	66.0	0.38	5.0	25.0	0.50	7.9	0.05	14	32.0	0.10	16.3	0.5
1940														
Jan.-Feb.	29 "	2	56.5	0.35	5.0	24.5	0.0	8.3	0.05	1	29.0	0.23	16.3	1.8
Unit No. 17—6-inch Cast-Iron, 30 Years Old—Test Started May 18, 1937														
1937														
May 24	6 days	1	75	0.4	5.0	22.0	1.0	7.9	0.14				12.5	
June	1 mo.	4	81.5	2.48	45.0	21.4	1.9	7.33	0.72				12.4	
July-Aug.-Sept.	3 "	10	81.5	4.5	22.3	23.2	1.0	7.57	0.35				13.18	
Oct.-Nov.-Dec.	6 "	9	59	0.58	5.0	22.6	0.1	8.1	0.06				14.6	
1938														
Jan.-Feb.-Mar.	9 "	5	51	0.52	5.0	21.0	0.0	8.26	0.045				16.0	1.5
Apr.-May-June	12 "	3	70	0.63	5.0	21.3	0.0	8.2	0.027			0.05	14.4	1.5
July-Aug.-Sept.	15 "	3	77	3.1	5.0	22.9	0.33	8.0	0.05	20		0.10	15.0	1.2
Oct.-Nov.-Dec.	17 "	1	49	0.3	5.0	24.0	0.0	8.4	0.05	13		0.3	15.8	2.0
1939														
Jan.-Feb.-Mar.	18½ "	3	50.5	0.7	5.0	21.9	0.0	8.2	0.04			0.18	14.5	1.6
Apr.-May-June	21½ "	3	74.0	0.56	5.6	23.5	0.0	8.2	0.05	10		0.15	14.86	1.6
July-Aug.-Sept.	24½ "	2	81.5	0.7	5.0	23.3	0.0	8.15	0.085	10		0.20	15.25	1.3
Oct.-Nov.-Dec.	27½ "	3	66.6	0.58	5.6	25.3	0.0	8.3	0.12	12	31.3	0.20	16.67	1.7
1940														
Jan.-Feb.	30 "	2	55.5	0.35	5.0	24.0	0.0	8.05	0.07	0	28.0	0.28	15.25	1.0
Unit No. 30—6-inch Aluminum-Alloy—Test Started Dec. 15, 1938														
1938														
Dec. 23	8 days	1	49	0.3	5.0	21.0	0.0	8.3	0.01			0.15	17.2	2.0
1939														
Jan.-Feb.-Mar.	3 mo.	3	47.2	0.4	5.0	23.13	0.0	8.27	0.01			0.05	14.5	1.7
Apr.-May-June	6 "	3	74.5	0.9	5.67	24.3	0.0	8.3	0.023	9.8		0.116	16.0	1.6
July-Aug.-Sept.	9 "	2	88.5	0.5	5.0	25.3	0.0	8.15	0.025	9.8		0.15	16.5	1.3
Oct.-Nov.-Dec.	12 "	3	68.3	0.4	5.0	25.3	0.0	8.26	0.033	9.8	32.0	0.15	16.83	1.5
1940														
Jan.-Feb.	14 "	2	57.5	0.3	5.0	25.0	0.0	8.3	0.02	0.0	29.0	0.175	16.75	2.0
Unit No. 31—6-inch Aluminum Alloy—Test Started Dec. 15, 1938														
1938														
Dec. 23	8 days	1	49	0.2	5.0	22.0	0.0	8.3	0.03			0.25	16.7	2.0
1939														
Jan.-Feb.-Mar.	3 mo.	3	47.2	0.4	5.0	23.5	0.0	8.27	0.01			0.08	15.5	1.8
Apr.-May-June	6 "	3	74.5	0.9	5.6	24.6	0.0	8.3	0.023	9.8		0.18	16.0	1.6
July-Aug.-Sept.	9 "	2	88.5	0.5	5.0	25.2	0.25	8.05	0.03	8		0.15	16.0	0.9
Oct.-Nov.-Dec.	12 "	3	68.7	0.4	5.0	25.3	0.0	8.3	0.027	10.8	32.0	0.166	17.17	1.7
1940														
Jan.-Feb.	14 "	2	58.5	0.3	5.0	24.5	0.0	8.05	0.02	0.0	29.0	0.175	17.0	1.8

TABLE 3—*Continued*

DATE	TIME IN TEST	AVE. NO. OF TESTS	TEMP. °F.	TURBIDITY	COLOR	HARDNESS	CARBON DIOXIDE	pH	Fe	% OXYGEN CONS.	DISSOLVED SOLIDS	RES. CHLORAMINE	ALKALINITY M.O.	ALKALINITY Phen.
Unit No. 32—6-inch Cast-Iron, Thin Cement Lining Seal-Coated—Started Dec. 15, 1938														
1938														
Dec. 23	8 days	1	49	1.0	12.0	33.0	0.0	9.6	0.09			0.20	35.2	21.3
1939														
Jan.-Feb.-Mar.	3 mo.	3	47.2	0.75	5.7	34.8	0.0	9.7	0.03			0.08	29.6	16.2
Apr.-May-June	6 "	3	74.5	1.3	6.6	30.7	0.0	9.4	0.05	10		0.10	25.0	10.9
July-Aug.-Sept.	9 "	2	88.5	0.6	5.0	33.0	0.0	9.3	0.07	9		0.15	25.0	9.9
Oct.-Nov.-Dec.	12 "	3	66.7	0.75	5.0	30.3	0.0	8.8	0.06	2	37.3		15.3	6.5
1940														
Jan.-Feb.	14 "	2	58.5	0.4	5.0	29.5	0.0	9.3	0.09	1	37.5	0.20	23.8	9.8
Unit No. 33—6-inch Cast-Iron Bituminous-Lined—Test Started Dec. 15, 1938														
1938														
Dec. 23	8 days	1	49	2.0	20.0	25.0	0.0	9.0	0.13			0.15	22.0	6.7
1939														
Jan.-Feb.-Mar.	3 mo.	3	47.17	0.7	5.7	23.2	0.0	8.3	0.04			0.03	13.0	1.9
Apr.-May-June	6 "	3	74.5	1.4	8.3	22.8	0.2	8.1	0.05	9		0.02	15.0	0.7
July-Aug.-Sept.	9 "	2	88.5	0.6	5.0	25.3	0.0	8.1	0.08	4		0.08	15.4	1.0
Oct.-Nov.-Dec.	12 "	3	66.7	0.5	5.0	24.3	0.0	8.1	0.06	7	32.3	0.12	17.2	1.3
1940														
Jan.-Feb.	14 "	2	59.5	0.4	5.0	23.5	0.3	7.9	0.09	0	28.0	0.08	15.5	0.3
Unit No. 34—6-inch Lehigh-Cement—Test Started Sept. 1, 1939														
1939														
Sept. 1		5				25.6	0.0	10.1					52.1	34.8
Sept. 2	2 days	2				49.0	0.0	10.3					48.5	35.0
Sept. 5	5 "	1				39.0	0.0	10.0					37.0	22.0
Sept. 6	6 "	1				51.0	0.0	10.4					47.0	33.0
Sept. 7	7 "	1				62.0	0.0	10.5					58.5	44.0
Sept. 20	20 "	8				42.9	0.0	9.95					38.9	24.6
Sept. 29	29 "	1		0.5	5.0	36.0	0.0	9.5	0.02	1		0.25	32.0	15.5
Oct.-Nov.-Dec.	4 mo.	3	66.7	0.63	5.0	31.3	0.0	9.25	0.03	2	42	0.23	25.5	11.3
1940														
Jan.-Feb.	6 "	2	59	0.25	5.0	29.0	0.0	9.0	0.02	0	35	0.28	24.0	7.0
Unit No. 35—6-inch Enameline "ACIPCO"—Test Started Sept. 1, 1939														
1939														
Sept. 1		5				24.6	0.0	8.74					18.1	5.2
Sept. 2	2 days	2				30.0	0.0	9.5					28.0	15.0
Sept. 5	5 "	1				29.0	0.0	9.3					24.5	11.0
Sept. 6	6 "	1				34.0	0.0	9.5					27.5	14.0
Sept. 7	7 "	1				31.0	0.0	9.4					24.5	10.0
Sept. 20	20 "	8				30.4	0.0	9.14					23.4	8.9
Sept. 29	29 "	1		0.4	5.0	34.4	0.0	9.5	0.02	4		0.25	30.3	14.5
Oct.-Nov.-Dec.	4 mo.	3	66.7	0.47	5.0	28.0	0.0	8.67	0.03	2	34	0.27	19.7	4.5
1940														
Jan.-Feb.	6 "	2	59	0.25	5.0	26.0	0.0	8.5	0.02	0	31	0.28	16.5	3.0

TABLE 3—*Continued*

DATE	TIME IN TEST	AVE. NO. OF TESTS	TEMP. °F.	TURBIDITY	COLOR	HARDNESS	CARBON DIOXIDE	pH	Fe	% OXYGEN CONS.	DISSOLVED SOLIDS	RES. CHLORAMINE	ALKALINITY M.O.	ALKALINITY Phen.
Unit No. 36—6-inch Cement-Lined "ACIPCO" Standard Portland-Cement—Test Started Aug. 31, 1939														
1939														
Aug. 31		5				49.6	0.0	10.88					79.0	64.5
Sept. 1	2 days	1				41.0	0.0	10.6					49.5	37.0
Sept. 2	3 "	2				42.0	0.0	10.4					49.3	36.0
Sept. 5	6 "	1				38.0	0.0	10.0					37.0	22.0
Sept. 6	7 "	1				39.0	0.0	9.8					32.0	19.0
Sept. 7	8 "	1				39.0	0.0	9.9					34.5	19.0
Sept. 20	21 "	8				38.25	0.0	9.7					32.9	19.0
Sept. 29	30 "	1		0.4	5.0	34.4	0.0	9.5	0.02	6		0.25	30.3	14.5
Oct.-Nov.-Dec.	4 mo.	3	66.7	0.4	5.0	30.67	0.0	9.17	0.03	1	38	0.27	22.5	8.2
1940														
Jan.-Feb.	6 "	2	59	0.3	5.0	27.50	0.0	8.9	0.02	0	33	0.28	19.5	6.0
Unit No. 37—6-inch Enameline "ACIPCO"—Test Started Sept. 6, 1939														
1939														
Sept. 6		4				25.3	0.0	8.77					17.7	6.0
Sept. 7	2 days	3				28.3	0.0	9.50					26.5	13.3
Sept. 20	15 "	8				33.9	0.0	9.43					28.0	13.6
Sept. 29	24 "	1		0.5	5.0	33.0	0.0	9.30	0.02	1		0.20	27.4	12.5
Oct.-Nov.-Dec.	4 mo.	3	66.7	0.5	5.0	28.3	0.0	8.83	0.02	1	35	0.25	20.0	5.7
1940														
Jan.-Feb.	6 "	2	59.5	0.3	5.0	27.0	0.0	8.70	0.02	0	33	0.25	18.8	4.5
Unit No. 38—6-inch Lumnite "ACIPCO"—Test Started Sept. 6, 1939														
1939														
Sept. 6		4				33.9	0.0	8.55					38.0	5.8
Sept. 7	2 days	3				39.8	0.0	9.07					34.8	10.0
Sept. 20	15 "	8				45.5	0.0	9.38					41.6	15.6
Sept. 29	24 "	1		0.5	5.0	31.4	0.0	8.90	0.02	7		0.25	26.8	7.0
Oct.-Nov.-Dec.	4 mo.	3	64.7	0.4	5.0	29.3	0.0	8.77	0.03	0	36	0.28	21.0	4.5
1940														
Jan.-Feb.	6 "	2	59.0	0.25	5.0	27.0	0.0	8.60	0.02	0	31	0.25	19.0	3.7
Unit No. 39—6-inch "ACIPCO" Modified Portland—Test Started Sept. 28, 1939														
1939														
Sept. 29	1 day	1		1.0	7.0	69.6	0.0	10.80	0.06	6		0.15	84.5	62.0
Oct.-Nov.-Dec.	3 mo.	3	64.7	0.47	5.0	33.0	0.0	9.33	0.05	2	49	0.28	26.8	13.3
1940														
Jan.-Feb.	5 "	2	59.5	0.25	5.0	28.0	0.0	9.00	0.02	0	35	0.25	20.5	7.8
Unit No. 40—6-inch Tate-Lined Cast-Iron—Test Started Aug. 26, 1939														
1939														
Aug. 26	1 day	6				335.0	0.0	11.08					144.7	122.5
Aug. 31	5 days	4				87.5	0.0	10.63					63.0	50.8
Sept. 20	25 "	13				59.5	0.0	10.49					54.6	41.4
Sept. 29	34 "	2		0.75	6.0	56.8	0.0	10.45	0.05	6	86	0.18	63.0	44.0
Oct.-Nov.-Dec.	4 mo.	3	64.7	0.47	5.0	33.3	0.0	9.50	0.03	5	46	0.28	28.5	14.5
1940														
Jan.-Feb.	6 "	2	60.0	0.35	5.0	35.0	0.0	9.50	0.02	0	47	0.23	27.5	14.3

TABLE 3—*Continued*

DATE	TIME IN TEST	AVE. NO. OF TESTS	TEMP. °F.	TURBIDITY	COLOR	HARDNESS	CARBON DIOXIDE	pH	Fe	% OXYGEN CONS.	DISSOLVED SOLIDS	RES. CHLORAMINE	ALKALINITY M.O.	ALKALINITY Phen.
Unit No. 41—6-inch Steel, Bituminous-Lined—Test Started Aug. 10, 1937														
1937														
Aug. 13	3 days	1	82	0.8	5.0	24.4	0.0	8.3	0.03				14.0	
Aug. 19	10 "	1	83	0.8	5.0	24.6	0.0	8.3	0.04				13.8	
Sept. 2	23 "	1	80	0.75	5.0	23.4	1.0	7.7	0.04				12.8	
Oct.	2½ mo.	4	67	0.53	5.0	23.0	0.5	7.83	Trace				14.1	
Nov.	3 "	1	58	0.5	5.0	23.0	0.5	7.7	0.02				15.2	
(Out of test 7 months)														
1938														
July-Aug.-Sept.	1½ mo.	3	77.3	0.37	5.0	22.5	0.5	7.8	0.017	12		0.02	14.1	0.3
Oct.-Nov.-Dec.	4½ "	1	49	0.3	5.0	23.0	0.0	8.2	0.02	1		0.20	15.8	1.0
1939														
Jan.-Feb.-Mar.	7½ "	3	50.5	0.47	5.0	21.7	0.0	8.03	0.02			0.10	13.6	0.8
Apr.-May-June	10½ "	3	74.5	0.36	5.0	24.1	0.33	7.91	0.036	10		0.05	14.6	0.5
July-Aug.-Sept.	13½ "	1	81.5	0.5	5.0	23.6	0.0	8.0	0.03	1		0.15	14.8	1.0
Oct.-Nov.-Dec.	16½ "	2	62.0	0.5	5.0	24.0	0.0	8.25	0.045	0	32.5	0.2	17.8	1.8
1940														
Jan.-Feb.	19 "	2	59.0	0.25	5.0	23.0	0.0	8.2	0.033	0	28.0	0.23	16.3	1.3
Unit No. 42—6-inch Transite—Test Started Jan. 10, 1940														
1940														
Jan. 10		1	58.0	0.2	5.0	38.0	0.0	9.50	0.02	0	48	0.15	32.0	17.0
Feb. 13	34 days	1	60.0	0.4	5.0	27.0	0.0	9.20	0.03	1	38	0.15	22.5	10.5
Unit No. 49—6-inch National Cast-Iron, Enameline—Test Started Nov. 26, 1939														
1939														
Nov. 26		1	61	2.0	12.0	30.0	0.0	8.90	0.21	6	38	0.20	22.0	7.5
Dec. 9	14 days	1	63	1.0	7.0	27.0	0.0	8.90	0.12	8	35	0.15	20.5	6.0
1940														
Jan. 10	44 "	1	58	0.3	5.0	28.0	0.0	8.70	0.15	0	33	0.10	19.0	4.5
Feb. 13	78 "	1	60	0.4	5.0	25.0	0.0	8.70	0.05	5	33	0.05	19.0	5.0
Unit No. 50—6-inch National Cast-Iron, Cement-Lined—Test Started Nov. 26, 1939														
1939														
Nov. 26		1	61	0.5	5.0	33.0	0.0	9.50	0.05	0	47	0.25	26.5	13.0
Dec. 9	14 days	1	63	0.5	5.0	30.0	0.0	9.50	0.05	0	44	0.25	26.0	14.5
1940														
Jan. 10	44 "	1	58	0.2	5.0	40.0	0.0	9.50	0.04	0	46	0.20	29.0	16.5
Feb. 13	78 "	1	60	0.4	5.0	36.0	0.0	9.90	0.03	0	57	0.15	36.5	21.5
Unit No. 18—¾-inch Copper—Test Started Oct. 24, 1937														
1937														
Oct. 24		1	61	0.4	5.0	23.0	1.0	7.6	Trace				13.5	
Oct. 30	6 days	1	60		5.0	22.6	1.0	7.5	0.01				13.5	
Nov.	1 mo.	3	55.7	0.5	5.0	21.6	0.3	7.8	Trace				14.9	
Dec.	2 "	2	50.0	0.5	5.0	21.3	0.0	8.2	0.01				15.1	

TABLE 3—*Continued*

DATE	TIME IN TEST	AVE. NO. OF TESTS	TEMP. °F.	TURBIDITY	COLOR	HARDNESS	CARBON DIOXIDE	pH	Fe	% OXYGEN CONS.	DISSOLVED SOLIDS	RES. CHLORAMINE	ALKALINITY M.O.	ALKALINITY Phen.
Unit No. 18—¾-inch Copper—Test Started Oct. 34, 1937—*Continued*														
1938														
Jan.-Feb.-Mar.	3½ "	6	52	0.6	5.0	21.5	0.1	8.17	0.005				14.9	
Apr.-May-June	6½ "	3	70	0.4	5.0	22.4	0.2	8.07	0.001			Trace	14.7	1.3
July-Aug.-Sept.	9½ "	3	77	0.47	5.0	21.9	0.3	7.93	0.017	8		0.02	14.2	1.0
Oct.-Nov.-Dec.	12½ "	1	49	0.4	5.0	22.6	0.0	8.0	0.05	5		0.20	16.0	0.5
1939														
Jan.-Feb.-Mar.	15½ "	3	50.5	0.55	5.0	21.1	0.0	8.0	0.017			0.13	13.7	1.1
Apr.-May-June	18½ "	3	73.0	0.6	5.7	23.1	0.2	8.1	0.03	3		0.12	13.8	1.1
July-Aug.-Sept.	21½ "	2	81.3	0.7	5.0	23.8	0.0	8.15	0.04	1		0.15	15.8	1.0
Oct.-Nov.-Dec.	24½ "	3	66.3	0.4	5.0	25.0	0.0	8.3	0.03	12	32.0	0.22	16.7	2.0
1940														
Jan.-Feb.	27 "	2	56.5	0.4	5.0	24.5	0.0	8.1	0.03	0	29.0	0.23	15.3	1.3
Unit No. 19—¾-inch Yellow Brass—Test Started Oct. 24, 1937														
1937														
Oct. 24		1	61	0.4	5.0	23.2	1.0	7.7	Trace				13.5	
Oct. 30	6 days	1	60		5.0	23.0	0.5	7.7	0.01				13.5	
Nov.	1 mo.	3	55.7	0.43	5.0	21.6	0.3	7.8	Trace				14.9	
Dec.	2 "	2	50	0.45	5.0	21.7	0.25	8.0	0.005				14.9	
1938														
Jan.-Feb.-Mar.	3½ "	6	52	0.5	5.0	20.9	0.0	8.23	Trace				14.9	
Apr.-May-June	6½ "	3	70	0.43	5.0	21.8	0.0	8.1	0.01			Trace	20.1	5.8
July-Aug.-Sept.	9½ "	3	77	0.37	5.0	22.5	0.2	8.0	0.013	11		0.03	14.7	1.0
Oct.-Nov.-Dec.	13½ "	1	49	0.4	5.0	21.0	1.0	7.6	0.04	7		0.0	15.2	0.0
1939														
Jan.-Feb.-Mar.	15½ "	3	50.5	0.52	5.0	22.2	0.13	7.9	0.03			0.07	13.5	0.7
Apr.-May-June	18½ "	3	74.0	0.47	5.0	23.2	0.17	8.03	0.05	5		0.05	15.3	0.9
July-Aug.-Sept.	21½ "	2	81.5	0.7	5.0	23.3	0.25	7.85	0.035	7		0.13	15.2	0.3
Oct.-Nov.-Dec.	24½ "	3	65.0	0.46	5.0	24.0	0.17	7.97	0.04	11	32.0	0.17	15.8	0.7
1940														
Jan.-Feb.	27½ "	2	58.0	0.3	5.0	24.0	0.5	7.85	0.02	1	29.0	0.12	15.0	0.8
Unit No. 20—¾-inch Steel-Galvanized, Cement-Lined—Test Started Oct. 24, 1937														
1937														
Oct. 24		1	61	0.5	5.0	47.2	0.0	9.9	Trace				37.0	
Nov.	1 mo.	3	55.7	0.6	5.0	32.7	0.0	9.27	0.007				26.2	
Dec.	2 "	2	50.0	0.63	5.0	35.8	0.0	9.3	0.005				25.8	
1938														
Jan.-Feb.-Mar.	3½ "	5	52	0.7	5.0	50.0	0.0	9.6	0.01				27.8	12.3
Apr.-May-June	6½ "	3	70	0.7	5.0	35.0	0.0	9.4	0.02			0.0	29.0	14.1
July-Aug.-Sept.	9½ "	3	77	0.33	5.0	33.4	0.0	9.2	0.013	2		0.02	26.6	11.2
Oct.-Nov.-Dec.	12½ "	1	49	3.0	10.0	30.0	0.0	9.2	0.12	8		0.25	25.0	10.8
1939														
Jan.-Feb.-Mar.	15½ "	3	50.5	0.8	5.0	32.0	0.0	9.5	0.03			0.03	28.1	12.8
Apr.-May-June	18½ "	3	74.0	0.63	5.0	34.4	0.0	9.37	0.05	7		0.05	26.6	10.4
July-Aug.-Sept.	21½ "	2	81.5	0.7	5.0	31.7	0.0	9.25	0.045	5		0.05	26.3	10.4
Oct.-Nov.-Dec.	24½ "	3	65.7	1.6	10.0	35.0	0.0	9.27	0.133	15	45.9	0.07	28.2	11.0
1940														
Jan.-Feb.	27 "	2	58.0	0.45	5.0	32.0	0.0	9.35	0.03	4	42.5	0.03	26.3	12.0

TABLE 3—*Continued*

DATE	TIME IN TEST	AVE. NO. OF TESTS	TEMP. °F.	TURBIDITY	COLOR	HARDNESS	CARBON DIOXIDE	pH	Fe	% OXYGEN CONS.	DISSOLVED SOLIDS	RES. CHLORAMINE	ALKALINITY M.O.	ALKALINITY Phen.
Unit No. 21—¾-inch Black Steel—Test Started Oct. 24, 1937														
1937														
Oct. 24		1	61	20.0	140.0	24.0	1.0	7.7	1.7				14.5	
Nov.	1 mo.	3	55.7	21.7	200.0	22.3	0.7	7.6	2.37				16.2	
Dec.	2 "	2	50	47.5	270.0	20.5	2.6	7.1	4.6				16.3	
1938														
Jan.-Feb.-Mar.	3½ "	5	52	16.8	208.0	22.9	1.6	7.9	2.5				16.9	2.0
Apr.-May-June	6½ "	3	66.5	11.7	73.3	23.3	0.0	8.4	0.67			Trace	16.4	2.2
July-Aug.-Sept.	9½ "	3	77	3.7	28.3	22.3	0.0	8.47	0.22	50		Trace	15.9	2.53
Oct.-Nov.-Dec.	13½ "	1	49	25.0	200.0	22.0	0.0	7.8	1.9	43		0.0	16.5	0.0
1939														
Jan.-Feb.-Mar.	15½ "	3	50.5	25.0	140.0	22.0	0.0	8.3	1.5			0.0	15.2	2.0
Apr.-May-June	18½ "	3	74.3	16.0	53.3	22.9	0.0	8.4	1.0	39		0.0	15.9	2.4
July-Aug.-Sept.	21½ "	2	88.5	15.0	50.0	22.8	0.0	8.45	1.45	38		0.08	15.9	2.6
Oct.-Nov.-Dec.	24½ "	3	66.3	14.0	130.6	25.0	0.3	8.1	1.43	42	31.7	0.08	17.7	1.5
1940														
Jan.-Feb.	27 "	2	58.0	10.0	100.0	24.5	0.0	8.55	2.05	40	28.0	0.08	16.8	3.3
Unit No. 22—¾-inch Steel-Galvanized—Test Started Oct. 22, 1937														
1937														
Oct. 24		1	61	15.0	80.0	29.2	0.0	8.2	0.03				23.3	
Nov.	1 mo.	3	55.3	11.7	78.3	26.9	0.0	8.6	Trace				26.7	
Dec.	2 "	2	50	16.0	85.0	26.5	0.0	8.7	0.01				22.0	
1938														
Jan.-Feb.-Mar.	4 "	5	51.6	151.0	126.0	68.3	0.0	8.56	0.02				92.2	
Apr.-May-June	7 "	3	70	16.6	88.3	26.0	0.16	8.37	0.01			0.0	23.4	2.6
July-Aug.-Sept.	10 "	3	77	21.7	76.6	24.0	0.0	8.43	0.01	23		0.02	21.1	2.6
Oct.-Nov.-Dec.	14 "	1	49	5.0	25.0	22.4	0.0	8.4	0.04	12		0.20	18.5	2.5
1939														
Jan.-Feb.-Mar.	16 "	3	50.5	19.3	66.7	24.8	0.0	8.6	0.03			0.02	22.4	3.5
Apr.-May-June	19½ "	3	74.3	13.3	46.7	25.5	0.0	8.4	0.03	7		0.08	20.3	2.3
July-Aug.-Sept.	22½ "	2	88.5	160.0	180.0	31.0	0.0	8.2	2.68	20		0.03	16.4	1.5
Oct.-Nov.-Dec.	25½ "	3	65.7	10.0	41.7	26.3	0.0	8.4	0.05	27	32.0	0.10	21.7	2.5
1940														
Jan.-Feb.	28 "	2	57.5	5.4	33.5	25.5	0.5	8.2	0.05	0	28.0	0.10	20.8	1.8
Unit No. 23—¾-inch Wrought-Iron, Galvanized—Test Started Dec. 3, 1937														
1937														
Dec. 3	1 day	1	50	20.0	80.0	28.0	0.0	8.5	0.03				23.0	
Dec. 31	28 days	1	50	18.0	80.0	24.0	0.0	8.7	0.01				23.5	
1938														
Jan.-Feb.-Mar.	3½ mo.	5	53	19.4	92.0	32.7	0.0	8.8	0.006				27.6	0.5
Apr.-May-June	5½ "	3	70	17.0	76.7	25.7	0.0	8.6	0.02				21.3	3.1
July-Aug.-Sept.	8½ "	3	77	16.7	55.0	25.5	0.0	8.4	0.02	25		0.017	21.1	2.5
Oct.-Nov.-Dec.	12½ "	1	49	15.0	80.0	23.6	0.0	8.5	0.05	11		0.20	24.0	3.0
1939														
Jan.-Feb.-Mar.	14½ "	3	50.5	25.0	113.7	26.7	0.0	8.6	0.033			Trace	25.9	3.4
Apr.-May-June	17½ "	3	74.3	11.0	35.0	25.5	0.0	8.3	0.033	16		0.083	18.3	2.1
July-Aug.-Sept.	20½ "	2	88.5	11.5	37.5	25.2	0.0	8.2	0.085	9		0.10	18.6	1.3
Oct.-Nov.-Dec.	23½ "	3	66.3	9.0	39.0	27.7	0.0	8.4	0.043	21	31.3	0.117	22.5	2.3
1940														
Jan.-Feb.	26 "	2	57.5	6.5	42.5	25.5	0.0	8.3	0.065	1	28.0	0.125	21.0	2.3

TABLE 3—*Concluded*

DATE	TIME IN TEST	AVE. NO. OF TEST	TEMP. °F.	TURBIDITY	COLOR	HARDNESS	CARBON DIOXIDE	pH	Fe	% OXYGEN CONS.	DISSOLVED SOLIDS	RES. CHLORAMINE	ALKALINITY M.O.	ALKALINITY Phen.
Unit No. 24—¾-inch Copper-Bearing-Steel-Galvanized—Test Started Mar. 17, 1938														
1938														
Mar. 17	1 day	1	58	3.0	15.0	23.6	0.0	8.3	0.03				16.0	1.2
Apr.-May-June	3 mo.	3	66.7	10.0	30.0	24.2	0.0	8.3	0.017			Trace	17.5	1.8
July-Aug.-Sept.	5 "	3	77	11.7	35.0	25.2	0.0	8.3	0.08	19		0.02	18.9	1.7
Oct.-Nov.-Dec.	9 "	1	49	1.0	17.0	23.6	0.0	8.3	0.06	11		0.15	17.8	1.8
1939														
Jan.-Feb.-Mar.	11 "	3	50.5	31.7	36.8	23.8	0.0	8.2	0.03			0.02	18.9	1.8
Apr.-May-June	14 "	3	74.3	6.0	20.0	24.8	0.0	8.3	0.08	9		0.10	16.5	1.6
July-Aug.-Sept.	17 "	2	88.5	7.5	22.5	26.3	0.0	8.1	0.085	9		0.10	18.1	1.3
Oct.-Nov.-Dec.	20 "	3	65.6	14.3	66.7	27.3	0.0	8.3	0.15	13	32.0	0.05	25.7	1.8
1940														
Jan.-Feb.	22 "	2	57.5	4.2	22.5	25.5	0.0	8.2	0.05	0	29.0	0.08	20.3	1.5

Development of Ann Arbor Water Supply

By H. H. Caswell

ON MAY 6, 1885, the Common Council of Ann Arbor, Michigan, approved the final draft of a contract for the construction and operation of a water works system, under a thirty-year franchise, by a private corporation to be known as the Ann Arbor Water Company. At the time, the city had a population of about 8,800 and the University of Michigan had a student enrollment of about 1,500. The entire water supply was obtained from private springs and wells. Ground water was so limited that in many parts of the city it was difficult even to locate such a supply, and neighborhood groups often found it necessary to obtain water for cooking and drinking purposes from some single source located in the vicinity of their homes. Every home, of course, had its cistern or its rain barrel from which necessary water for laundry and bath purposes was obtained. Large cisterns were also located throughout the business district where roof water was collected for fire protection purposes, and the old bucket brigade had to be called into play for fire protection in the outlying districts.

Plans for the original water plant were made by Professor Chas. E. Greene of the University of Michigan, and he also supervised the construction work. The plans called for the establishment of a complete water system, including adequate pumping facilities; an open earth embankment reservoir of 2,000,000 gal. capacity, with facilities for draining and cleaning (which were not provided); the laying of 14 miles of cast-iron water mains, and the installation of 50 gate valves and 105 fire hydrants. The company agreed to furnish "at all times a sufficient supply of good water suitable for domestic purposes and this at a reasonable rate." For the general service provided the

A paper presented on September 13, 1940, at the Michigan Section Meeting, Ann Arbor, by H. H. Caswell, Manager, Ann Arbor Water Department, Ann Arbor, Mich.

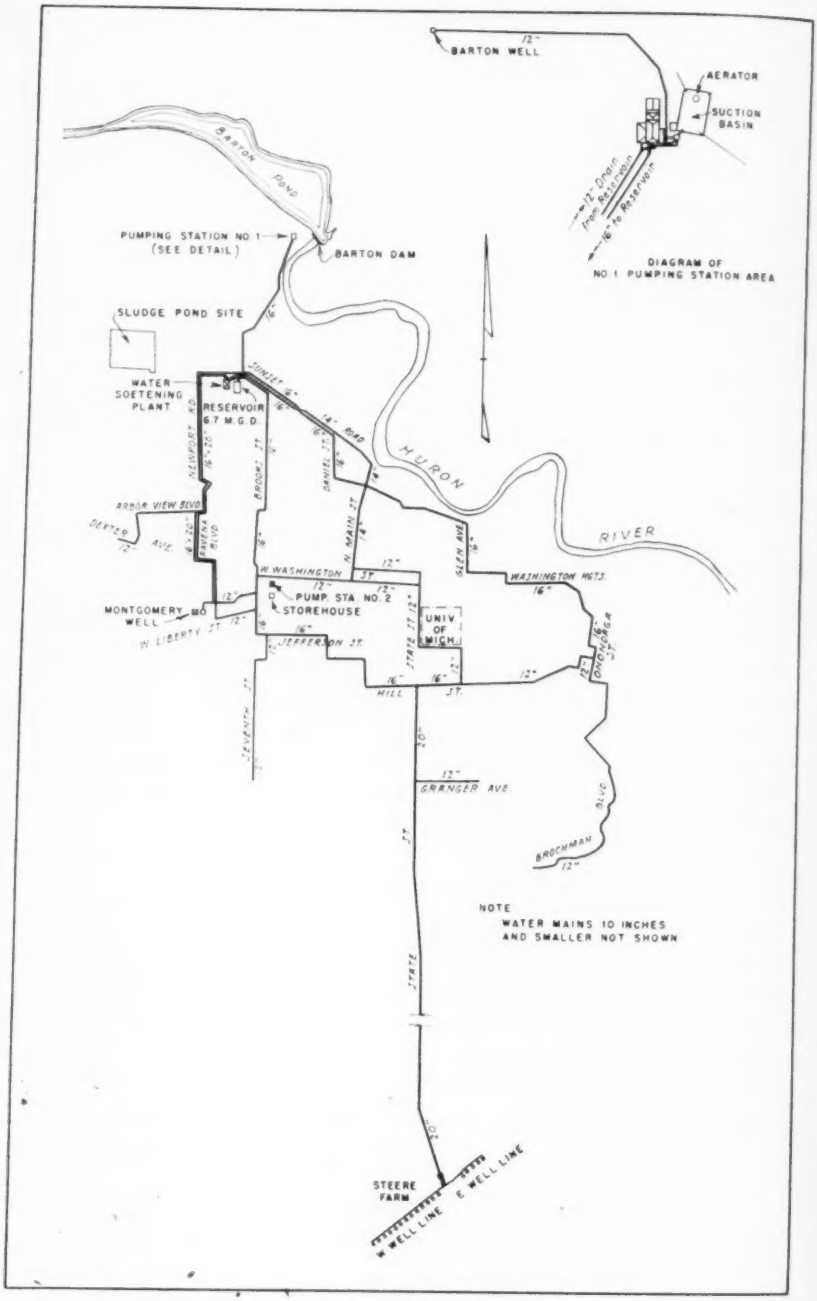


FIG. 1. Ann Arbor Supplies and Transmission System

community, the City agreed to pay $4,000 per year, plus $40 per year for each additional fire hydrant. The system was to be completed in December, 1886, at a total cost, as reported upon the request of the council, of $200,000.

The pumping plant was located on the site of what is now Pumping Station No. 1 on the Huron River near Barton Dam (see Fig. 1). The original pump house is still in use. The water supply was to be obtained from springs on the premises, and from a creek on the Allen Farm on the opposite side of the river. The water was piped to the receiving basin (which is still in use) east of the pump house and from there it was pumped to the reservoir. The combined daily flow from these sources was estimated to be from 400,000 to 450,000 gal. The original reservoir was located on the present reservoir site where it was in continuous use until replaced in 1931.

The test specifications upon which the adequacy of the system for fire protection was determined read as follows: "The works shall be capable of throwing, by reservoir pressure, six streams eighty feet high at the Court House at one time, and by direct pump pressure the same number of streams at the same place one hundred and ten feet high."

Controversy With Water Company

Things appeared to move along quite smoothly at the start of operation. Trouble did start in 1888, however, when in August of that year the report of the Board of Health raised certain issues relative to the animal pollution of the surface water being furnished. The Board of Health was somewhat appeased by the efforts of the water company to clear up the situation.

As time went on, a controversy arose over the adequacy of the fire protection being provided and the rentals being paid for this service. It appeared that many hydrants were found not readily usable in the winter because of ice around the outlets formed from water draining into the holes in which the hydrants were set. Other hydrants could not be located easily because of the snow piled around them in cleaning off the sidewalks. Complaints also arose concerning the condition in which streets were left after construction work.

After incessant hammering it appeared that the Water Company did make an effort to relieve the situation that had developed. In 1896–97 a new pumping station (No. 2) was located on West Washington on the site of the present storehouse (Fig. 1). This was a

steam plant with a capacity of 1½ m.g.d. Its supply was taken from a series of artesian wells drilled on the site and from several collecting galleries located in a nearby valley. It appeared for a few years following the development of this new source of supply that the battle between the water company and the city had to some extent subsided. In 1900, however, hostilities again opened with increased intensity—this time over rates.

During the period from 1900 to 1910, as much water as possible was being taken from the two existing artesian sources, the balance being taken from the river. The amount taken from the river was steadily increasing and as there was no storage basin in the river at that time, there were a number of periods throughout the year when the water carried considerable amounts of sediment.

First Treatment Plant

In 1910, Ann Arbor's first treatment plant was built. A 3-m.g.d. low lift pump was installed to deliver raw river water to a rapid sand filter. The filter consisted of a brick box type structure with a bed of pea gravel over a collecting grid. The water flowed from the filter by gravity to an ozone treatment house and from that to the receiving basin for delivery to the city. Although there is very little information available concerning the ozone plant, there are indications that it did operate with some degree of success for a short time. In a report on the valuation of the properties of the Ann Arbor Water Company made for the council by Gardner S. Williams in January, 1912, the following statement concerning the ozone plant is to be found:

"The water drawn from the river has, during the past year, been purified by treatment with electrically generated ozone in a plant whose present rated capacity is 2,000,000 gallons per 24 hours. All apparatus and construction included therein, except the ozone generators, are of 3,000,000 gallons capacity. A 24-hour test of this plant in April, 1911, prior to its acceptance by the water company, showed a capacity of 2,000,000 gallons and a reduction of bacteria from 21,400 per cubic centimeter in the raw water to an average of 26 in the purified water when samples were incubated at a temperature of 37° C. for 48 hours. The samples were taken every three hours from a tap at the pumping station, the highest count of bacteria being 35 and the lowest, 20. No pathogenic or colon bacteria appeared in the effluent, though they were abundant in the river water. This repre-

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sents a high degree of purification, and in this condition the purified water is probably better than the ground water as usually supplied. It has not been found possible to determine the cost of purification closely, but it is probably less, where fixed charges are concerned, than the cost of purification by means of filtration, though somewhat higher than by use of calcium hypochlorite. As the ozone plant can hardly be considered out of the experimental stage, it may be that on account of cost of operation, or the possible rapid deterioration of the parts of the apparatus, or for some other, now unsuspected, reason, its use will not be considered entirely satisfactory in the future, and plans have therefore been made for a slow sand filtration plant." It is understood that this ozone plant operated for only a short time. It was abandoned in 1915, when liquid chlorine came into use, and a chlorinator was installed.

Purchase by City

The presence of an artesian water supply on a farm about three miles south was brought to the attention of the city in 1912. An option on the land was taken, and several test wells were drilled. With this new-found source of supply, agitation for municipal ownership in 1915, when the franchise of the water company expired, gained momentum.

A vote on the proposition of purchasing the property of the Ann Arbor Water Company failed by two votes in April, 1912. Another vote was taken in May, 1912, and failed by 486 votes. The failure of these two votes was due to an organized objection based on the price for which the company agreed to sell. In October, 1913, a vote was taken on the proposition of purchasing the Steere farm property, as a source of supply, for $20,000 and for the purchase of the property of the water company for $450,000, the purchase date being set for January 31, 1914. Both propositions carried and arrangements were started immediately for taking over the operation of the water property as a municipally owned utility.

An ordinance, creating the Ann Arbor City Water Department, was adopted December 1, 1913. This ordinance has been in effect since that time with but two minor changes in the original draft. It might be well to give a brief account of the set-up under which the department operates.

Under the terms of the water works ordinance, all business connected with, or pertaining to, the water works system of the city

is to be transacted and controlled under the management and direction of the water works department. The department is operated and controlled by a board of water commissioners consisting of three members elected by the Common Council for six-year terms, staggered two years. The affairs of the department are administered by the manager who is hired by the board. The department is responsible for the collection of all monies due for the service rendered, such monies being deposited in a special fund from which it is drawn only by order of the Board of Water Commissioners. Water rates are established by the council and in the ordinance, the council retains to itself the jurisdiction of water use outside the city limits. The commissioners now serve without pay although, until amended in 1933, the ordinance provided that they receive $20 per month compensation.

Inventory of Property Purchased

At the time of transfer of ownership, the property of the Ann Arbor Water Company consisted of the following:

1. The Washington Street pumping station containing two steam pumps with a total rated capacity of 3.5 m.g.d., taking water from artesian sources in the ravine between West Washington and West Liberty Streets. The yield at this station did not exceed $\frac{3}{4}$ m.g.d. at that time.

2. The No. 1 Pumping Station, containing three steam pumps of a total capacity of 8.3 m.g.d., and taking water principally from the Huron River. The relatively small amount of artesian water from the natural flow of the wells at this station was pumped directly to the reservoir without treatment, while the river water received chlorination.

3. Two reservoirs—the original open embankment one on Sunset Road, on the site of the present reservoir, and an elevated storage tank on Onondago Street (since removed).

4. A system of 40.4 miles of cast-iron mains.

With the exception of a few large industries and the University, all water services were upon the flat rate payment basis.

For the first few years, the Board of Water Commissioners struggled along, managing the plant with unsatisfactory rates and with the original sources of supply. The demand for water had long since outgrown the available artesian supply, and the river was being called upon more and more frequently to meet the deficiencies.

Installation of Meters

In April, 1918, a bond issue was passed, authorizing the construction of a pumping station at the Steere Farm (south of the city) and actual work was started in July of that year. The plant was put into operation in July, 1919. This station supplied 3.5 m.g.d. of artesian water, but since the department was operating on a flat rate schedule even this addition to the artesian source was not sufficient to meet the peak demands. It became evident that it would be expedient to install meters on all services. In 1920, a bond issue was passed for this purpose and the city was metered completely, just as rapidly as the change-over could be made conveniently. The initial effect of completely metered service was to reduce the consumption of water from an average of about 4.25 to 2.25 m.g.d.

Soon after the start of pumping at the Steere Farm Station, land owners in the vicinity of the site started action to enjoin the city from continuing to pump, because of alleged damage being done to their land and crops. A settlement was made with the objectors by separate contracts at a total cost of about $81,000. At a later date when another group of farm owners made an effort to collect damages, the city stood suit and the Circuit Court returned a verdict in favor of the city. This decision was appealed, reviewed and upheld by the State Supreme Court.

Inadequacy of Artesian Supply

In 1922, the State Board of Health condemned the water at the Washington Street Pumping Station and forced its abandonment as a source of supply. From July, 1919, until May, 1923, the water supply of the city was wholly artesian. In May and June of 1923, however, river water was required during the period of repair to the Steere Farm plant. In 1924, some pumpage from the river was required in July; and in 1925, river pumpage was required for the first six months of the year, due to the dropping off of the quantity available from the Steere Farm source. Due to deficient rainfall, or other reasons, the water stage of the wells at this station approached the limit for the pump installation. In consequence, the station was operated on short intervals daily to yield about one-half the daily requirements of the city.

In a communication to the Common Council, the Board of Water Commissioners advised as follows: "Your Water Commission is at

the present time confronted with a very serious problem, the solution of which is beyond the authority of the Commission. We feel that the entire capacity of the Steere Farm supply has been utilized, but has been found to be inadequate in times of maximum demand."

The Board of Water Commissioners, acting upon the recommendations in a report by Maury & Gordon, placed a recommendation before the council for the construction of a filtration plant with the Huron River as the source of supply. The controlling sentiment, however, appeared still to be in favor of an artesian supply, and further explorations were ordered.

In November, 1927, a proposition was put before the voters calling for a bond issue for the construction of a new reservoir, connecting of dead-end mains, and the development of an artesian water supply. This was defeated.

New Wells and Reservoir

The Council ordered additional explorations for a ground water supply, and, when it appeared that this supply had been located, ordered the construction of two deep well pumping stations. One well was completed and put in service in the western part of the city. It had a rated continuous delivery of 3 m.g.d. Another well was located on the Pumping Station No. 1 site and this had a rated capacity of 2.75 m.g.d. These wells cost the water department $85,000.

Gardner S. Williams was very critical of the action of the council in ordering the construction of these wells, and, in a public address, strongly advocated that the Huron River be used as the source of supply. He warned that, though it appeared the citizens were resolved to a ground water supply, they were traveling along a dangerous and costly road.

It did appear that with this additional ground water supply the problem of quantity had been solved for a while at least, but other improvements in the system were necessary. The old open reservoir had long since been inadequate to render proper service, and the character of the water was such that dead-end conditions were fast becoming a problem. In 1931, a proposition was put before the voters calling for the construction of a new reservoir, the connecting of dead-end mains, and the construction of a feeder main. There was no request for an expression of sentiment on source of supply at this time, and the proposition was carried by a large majority.

The improvements authorized in this bond issue were started immediately and were carried to completion as rapidly as possible. A new fully enclosed concrete reservoir of 6 mil. gal. capacity was built. This reservoir was built in three sections with provisions for cleaning each section separately. By careful arrangement of the inlet and outlet pipe, provision was made for insuring a uniform flow of water through the structure. A complete system of drains was installed under the floor slab and around the side walls, and to date there is no evidence of any leakage.

All dead-end mains were eliminated where it was reasonably possible to do so. Reinforcing mains were constructed in the east and the west sections of the city.

Demand for Improved Quality

The presence, on the line, of this new reservoir resulted in immediate pressure improvements. It provided the reserve with which to maintain more uniform pressure during the periods of heavy consumption. These improvements, however, did not fully solve the water problem, although the presence of the reservoir did almost eliminate the necessity for the use of river water at the time. Although the sentiment still appeared to be in favor of ground water, complaints began to mount on the quality of the water being provided. Due to the necessity for maximum pumping from all available ground water sources, the water was becoming extremely hard, and the presence of iron was becoming more and more a source of complaints. The demand for an improved quality of water was constantly being brought under discussion; and in 1935, when it appeared that the demand had reached the point where determined action must be taken, the proposal for the construction of a water softening plant was brought up for consideration. From its reception, it appeared that the time was ripe for action and authorization was granted for the request for a P. W. A. grant to cover construction. After two years of waiting for some action on the request, however, the plan was abandoned; and since the financial position of the department was very sound, it appeared that with a little help the project could be put on a cash basis. When these facts were made known, a strongly determined Board of Water Commissioners and an equally determined Council submitted the idea and it received immediate and unqualified approval by the public.

New Softening Plant

The Board of Water Commissioners authorized a comprehensive study of all ground water sources in the area, and these records have been filed for future reference. The question of source of supply, however, was entirely divorced from the question of water softening, and left for future review and decision. The problem resolved itself into that of constructing a plant, in such a location, and of such design, as would accomplish its purpose regardless of the type of water provided.

Through a rate increase of 50 per cent for one year (1936), an additional $72,000 in receipts was realized. The entire water softening project, including the plant and the necessary changes in mains, was constructed at a cost of about $525,000, the total amount paid in cash. There still remains the construction of the sludge disposal units to make the project complete. Land has been purchased for this purpose, and the work of preparing the site is now in progress. The first stage of the program will be completed at the end of 1940.

Water Softening at Ann Arbor

By Louis E. Ayres

A HALF-CENTURY long controversy over the quality of the water supply of Ann Arbor, Michigan, came to a happy conclusion when a modern water softening and purification plant was placed in operation. This paper deals with the principal design problems involved in collecting, softening and distributing the improved supply.

The resident population of Ann Arbor increased from 26,944, in 1930, to 29,721, in 1940, a growth of slightly over ten per cent. Also, the enrollment in the regular session at the University of Michigan increased from 10,000 to 13,000, and the summer school attendance from 3,600 to 5,600 during the decade. Taking into account the seasonal fluctuations of the University population, one may say that the average annual total population of Ann Arbor has increased in the last ten years from 35,000 to 40,000, or about 14 per cent.

The average pumpage in 1939 was 4.73 million gallons per day, a per capita use of 118 gal. On a maximum summer day the use exceeds 9.0 m.g.d., or 250 gal. per capita, and a maximum hourly rate in excess of 18 m.g.d. has been experienced. In the last five years the water requirements of the city have increased about 12 per cent, or at a rate of $2\frac{1}{2}$ per cent per year. The services are fully metered.

The existing sources of supply to be considered were:

(1) A group of relatively shallow wells located about $2\frac{1}{2}$ miles south of the city (known as the Steere Farm supply), capable of a peak delivery of about 3.0 m.g.d.

(2) A single 26-inch gravel-packed well located at the westerly

A paper presented on September 13, 1940, at the Michigan Section Meeting, Ann Arbor, by Louis E. Ayres, Civil Engineer, Ayres, Lewis, Norris & May, Ann Arbor, Mich.

city limits, known as the Montgomery Well, and capable of a peak delivery of about 2.0 m.g.d.

(3) A single 26-inch gravel-packed well located one mile north of the city, known as the Barton Well and capable of a peak delivery of 1.5 m.g.d.

(4) An emergency river supply from the Huron River, adjacent to the Barton Well and capable of supplying, during minimum river flow, at least two and one-half times the present requirements of the city.

[*For the location of the various parts of the system, see Fig. 1 in the paper by H. H. Caswell, immediately preceding this paper in this issue of the* JOURNAL.]

Nature of Supply

A comprehensive survey of ground water resources of this area had been made and the conclusion reached that additional ground water, if and when needed, should be sought further to the west of the city than the Steere Farm supply is to the south.

It thus appears that the total available well supply is now appreciably less than the demand of the maximum day. It was somewhat less in 1934, just prior to the studies on the new plant, and had no reserve for breakdown, except the stored water in a 6 mil. gal. covered reservoir, constructed in 1931. The deficiency is now met by the treatment of a combined surface and ground supply in such proportions as seem most advantageous. How fortunate the city was in securing a new plant under such conditions can be fully appreciated only by men responsible for municipal water supplies.

Without presenting tabular analyses, the character of the water supply may be indicated in round figures as follows: All well water carries a carbonate hardness of about 300 p.p.m., the Huron River about 200 p.p.m. The Steere Farm supply has a non-carbonate hardness of from 100 to 150 p.p.m., while the other sources range from 50 to 70 p.p.m. The magnesium content of the well water may be averaged at about 30 p.p.m. and of the river water at 20 p.p.m. All well water carries about 1.5 p.p.m. of iron. The river water is normally low in turbidity, color, taste and odor. Contamination is limited to the treated effluent from one small village, from cottages on upstream lakes and from other recreational uses of the river.

The first questions to be decided were: (1) whether to bring the water from the several sources to a central point, or to treat the Steere

Farm supply separately, and (2) if a single plant were to be adopted, where would it be located.

The distance, as the crow flies, between the Steere Farm to the south and the Barton Well to the north is more than six miles. Each source of supply was fed directly into the distribution system, one from the north, one from the west and one from the south, with an equalizing reservoir at the northwest corner and a large proportion of the population in the southeastern part of the city. The topography of the city resembles a bowl, with the business district and University campus in the bottom and the storage reservoir on the rim opposite the heaviest residential area. Static pressures from the reservoir amount to 50 to 60 lb. downtown, but reach a minimum of 25 lb. on the highest points on the rim, two to three miles distant from the reservoir. Hence, it was found necessary, in order to maintain suitable pressures in the east side of town during maximum demand, to pump the Steere Farm supply in from the south at somewhat increased pressures.

The use of a single plant, to the west of the city, required, therefore, not only that the raw water be brought to a common center, but that new provision be made for its subsequent distribution to the rim of the bowl in sufficient quantities to meet heavy sprinkling loads. The separate treatment of the Steere Farm supply, on the other hand, involved a minimum of disturbance of the existing distribution system and hence a minimum of expense for new mains. Also, with its relatively large proportion of sulfate hardness, the separate softening of this supply in a zeolite plant was a possible solution.

Such a plan might have been followed if the quantity of Steere Farm water had justified the expectations when the supply was developed in 1919. At that time it was assumed, based on tests and the advice of engineers and a geologist, that the area would provide a permanent supply for the city for years to come. The experience of 15 years of pumping had, however, proved otherwise. Yielding 3.5 m.g.d. over some period of time, these wells are not now to be depended upon for more than one-half that amount continuously. For years, to meet the demands of the city, they were pumped beyond their safe yield. Originally, the artesian water in the area had a hardness of only 250 p.p.m., but as the supply was drawn from ground storage the hardness increased, and in recent years the output has reached a total hardness of 450 p.p.m. Apparently, then, the quality

and quantity of this supply did not appear to warrant its separate treatment.

The remaining sources of supply, as already noted, were to the west and north of the city, in the Montgomery and Barton Wells and the Huron River, and any further well development would be to the west. Also, at about the center of these sources was the storage reservoir from which distribution mains led into the city. Hence, at or near the reservoir appeared to be a logical location for a plant, if a mixed surface and ground water were to be treated; or near the river intake, if surface water alone were to be used.

As already indicated, the Huron River, from the standpoint of quality, quantity and upstream contamination is a satisfactory source of raw surface supply. An intake, in about 25 ft. of water, just upstream of a power dam of the Detroit Edison Company, was already provided. The chief drawback, in a community accustomed to a well supply, was temperature, and also the possibility of minor seasonal taste and odor objections, even after treatment. Further, the community had long been divided by a controversy over river and well waters, and the opinion had prevailed that the source of supply must be settled before it was feasible to plan treatment. Although the estimates indicated some financial advantage in abandoning well water for a river supply, such a plan would have run contrary to the desires of a portion of the consumers, and would have resulted in a somewhat less satisfactory product.

Plant Location and Design

The plan adopted, therefore, was the location of a single plant near the existing reservoir and the transportation of all existing supplies thereto. It required the construction of certain raw water supply mains, a plant designed to treat a combination of surface and ground water, and special provision for the distribution of the treated water. The plan contemplated the use of well water to the extent that it might be available, and relief for the wells during such periods as the river supply was cool and low in turbidity. If the plan proved satisfactory to consumers it would provide a permanent solution of the water problem. If, however, the product of the plant failed to meet temperature or taste requirements of the public, the city would be confronted with the need to seek further ground water. In other words, in order to meet a critical situation involving public controversy over source of supply, it was decided to

proceed first with the development of a plant that would treat either supply, and to postpone until later the decision as to the ultimate source. It may be added that, under competent direction, the plan has succeeded. After nearly two years of operation in the treatment of a combined surface and well supply, the water problem is no longer an active public issue. The treated water is cool, clear, soft, free from iron, and meets with general approval.

The new plant was built on the highest ground available, immediately west of the existing covered storage reservoir. As this reservoir, with a water depth of 18 ft., is built largely above ground, it was necessary to pump all treated water from the plant clear well into storage, against an average head of about 20 ft.

The plant capacity was fixed on the assumption that provision should be made to meet a maximum demand about 50 per cent in excess of current demand; and this basis anticipated twenty years of growth. The design further provided for an increase of an additional 50 per cent in capacity by adding more filters and another unit for flocculation and settling.

The plant design incorporates standard practice in its several units and is completely provided with the facilities necessary for its variable service. A brief description of the several units, the design bases and the equipment is given below.

[*For a flow diagram of the plant, see Fig. 2 in the paper by H. E. McEntee, immediately following this paper in this issue of the* JOURNAL.]

Mixing and Aeration

The mixing, settling and carbonation tanks are in duplicate units (Fig. 1), and the hydraulics permit either series or parallel flow through these units to the filters. The primary and secondary sludges are returned separately and either may be delivered to waste or to the secondary flash-mix.

On entering the plant the raw water is passed over a cascade-type aerator (Fig. 2), constructed of two sets of galvanized sheet steel pans, resting on a concrete collecting apron built above the secondary flocculation basin. In each set of pans the water falls 4 ft. 6 in., in three equal steps. The weir lengths of the successive steps are 40, 80 and 160 ft. respectively.

Two rectangular concrete tanks 10 ft. x 10 ft. in plan with an average water depth of 14 ft. provide about one-minute detention for a future maximum rate of 15 m.g.d. Each mixing tank has a vertical

FIG. 1. Rear View, Showing Facilities for Dual Operation

FIG. 2. Cascade Type Aerator

shaft mechanical agitator, 54 in. in diameter, similar to a centrifugal pump impeller but mounted at an angle with the shaft. The shafts rotate at 31 r.p.m., and each shaft is driven by a 3-h.p. motor mounted on a vertical speed reducer. Water and chemicals enter the tanks at the bottom and the mixed water flows out at the top, over a weir into the distributing channels leading to the flocculating basins.

Flocculation

Two rectangular flocculation basins, each 50 ft. by 45 ft., with an average water depth of 12 ft., provide substantially 30 min. of detention each for 10 m.g.d.

The flow from the distributing channels to the flocculating basins is controlled through the manual operation of four 24 x 24-inch equally spaced sluice gates, and the flow out of the flocculating basin is through a redwood outlet baffle of 2 x 8-inch verticals, spaced 3 in. apart. Each basin is divided into three sections by redwood baffles, extending down from the surface to about one-half the water depth. In each section there is a horizontal steel shaft 50 ft. long, driven, through bevel gears, by a vertical gear motor of 1 h.p., at 2.16 r.p.m. On this shaft there are four steel paddles 9 ft. 6 in. in diameter, each with two blades. These paddles rotate so that the bottoms sweep toward the inlet.

Settling

Two rectangular settling basins, each 50 ft. wide by 140 ft. long, with an average water depth of about 12 ft., provide 90 min. detention each for 10 m.g.d. The inlet is through the outlet baffle of the flocculating basins, and the outlet over a weir at the opposite end. Each settling tank is provided with three lines of straight line collector and a cross collector into a sludge hopper at the inlet end, all driven by a single 1-h.p. motor. The 2 x 8-inch flights are spaced 8 ft. apart and travel at the rate of 2 ft. per min.

The sludge from each basin is collected separately through cast-iron sludge lines, leading through a gallery to the basement of the building. Sludge pipes discharge by gravity into either of two concrete inspection tanks where throttling valves control the flow. From one tank, secondary sludge may be pumped back to the secondary basin by a pump having a capacity of 100 g.p.m. The disposal of primary tank sludge will be discussed later.

Carbonation

Running the length of the flocculating and settling basins, and between these basins, are two carbonating channels, each 180 ft. long by 5 ft. wide, with an average water depth of 12 ft., providing about 11 min. detention for a flow of 10 m.g.d. Carbon dioxide gas may be distributed to the bottom of these channels through a brass pipe grid system with laterals spaced 2 ft. apart, having $\frac{1}{16}$-inch holes on 3-inch centers.

Carbon dioxide gas may be supplied from the basement of the building by a coke furnace and scrubber with a capacity specified at not less than 3,000 lb. per hr. and a blower with a capacity of 180 cu.ft. per min. at a pressure of 7 lb. per sq.in.

Chemical Handling and Feeding

Lime and soda ash are delivered to the plant by truck since no railroad siding is available at the plant site. These chemicals are elevated about 50 ft. into the tower by a dustless pneumatic conveyor system, having a capacity of 5 tons per hour, and dropped into rectangular concrete bins, from which they flow by gravity to the chemical feed machines. There are three lime bins with a total capacity of 200 tons and two soda ash hoppers with a total capacity of 30 tons. The lime storage was estimated as sufficient to meet the plant requirements for three weeks at a rate of 10 m.g.d. of water, and the soda ash storage, equal to a carload lot, is sufficient for six weeks or more.

Alum, if needed, and activated carbon are handled in bags by an elevator to the second floor. The bag storage would accomodate carload lots of these materials.

Three lime feeders proportion and slake quicklime continuously, by weight, and feed the milk of lime through rubber hose to the flash mixer. Each lime feeder is mounted below a lime storage bin and each has a capacity of 500 lb. per hr. There are three smaller volumetric chemical feeders for soda ash or alum, each with a capacity of 50 lb. per. hr., and each with a one-ton hopper which may be loaded by spouts from the bins or from bag storage. Also, an activated carbon feeder is located in the bag storage room.

Filtration

The plant contains six rapid-sand filters, each having a sand area 17 ft. by 27 ft., or 459 sq.ft., which provides a capacity of 7.5 m.g.d. at the standard rating of 2 g.p.m. per sq.ft., or 11.25 m.g.d. at 3

g.p.m. per sq.ft. The latter rate was expected more nearly to approximate experience under the local conditions. The filters are arranged along both sides of a gallery 20 ft. wide (Fig. 3). Piping and structures are designed to provide for the addition of two more filters at the west end of the gallery when that becomes necessary.

The filter layers are composed of 18 in. of gravel, graded from 3 in. to $\frac{1}{16}$ in., covered with 24 in. of Ottawa sand, with a mean effective size of 0.45 to 0.55 mm., and a uniformity coefficient of 1.20 to 1.40.

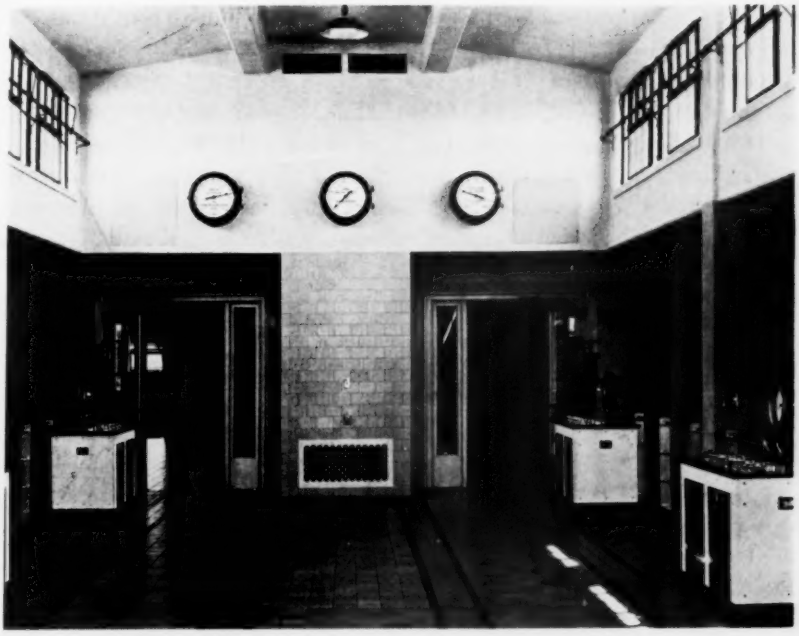

FIG. 3. Filter Room

Sizes and grading of sand were specified to be determined by the methods described in the *Manual of Water Works Practice*.

The underdrainage system is of cast-iron pipe, with 3-inch laterals spaced on 12-inch centers with $\frac{3}{8}$-inch brass bushed holes at 3-inch centers, staggered in the lower quarters of the pipe. The collector manifold is 24-inch cast iron, embedded in concrete in a trough in the filter floor.

The underdrains and laterals and wash water system are designed to provide a wash water rate of rise of 36 in. per min. for 5 min.

The filter gallery piping is of cast iron with the exception of the settled water conduit which is forged steel flanged pipe, 48 in. in diameter at the entrance to the gallery, coated inside and out, and covered on the outside with anti-sweat insulation. This conduit will permit a maximum, eventual velocity of 1.8 ft. per sec.

Wash water is supplied from horizontal water tanks in the tower, on either side of the chemical storage bins. These tanks are 11 ft. 3 in. in diameter, with bottoms 32 ft. above the sand surface in the filters, and have a total capacity of 48,000 gal. The wash water pump has a capacity of 750 g.p.m., requiring one hour to fill the tanks.

The filter effluent piping discharges into water-seal chambers with discharge weirs at a height sufficient to prevent formation of a vacuum in the piping or rate controllers.

The wash water from the filters drops into a cistern, located below the gallery floor, and of sufficient capacity to hold one filter wash. From there it is pumped to the flash mix for re-use. A small sewer is also available for the gradual release of this water, should such procedure ever prove desirable. Operating experience to date, however, indicates that this waste water is of value in the operation of the settling basins, and it is more economical to return the waste water than to supply its equivalent from the raw water sources.

The six filter rate controllers are connected to a totalizing device which in turn actuates an automatic chlorinator for the sterilization of the filtered water.

The water from the chlorinating chamber flows into a small clear well under the main building, from where it is pumped by one or more of three float-controlled vertical pumping units, through an average head of 20 ft., into the 6 mil. gal. storage reservoir.

Disposition of Sludge

As already stated, the primary and secondary sludges are separately collected and brought by gravity to inspection tanks in the basement, and the secondary sludge is returned to secondary settling. Three provisions were made relative to the disposal of the waste sludge. First, it could be discharged into a sanitary sewer to find its way to the sewage disposal plant. Second, it could be discharged into a storm sewer and so to the Huron River. And third, it could, and will soon, be discharged to settling ponds on land to the west of the plant.

It was anticipated that only a relatively small portion of the

sludge output of the water plant could ever be advantageously handled at the sewage treatment plant, as the dry weight of water softening sludge will run over three times the dry weight of sewage solids. It was thought, however, that a certain amount of lime sludge would be advantageous to the sewage plant, but experience to date does not indicate that any appreciable quantity can be so used. This is another story beyond the limits of this paper.

To date most of the sludge has gone to the Huron River, and although its point of entry into the river is well isolated from the public, complaints have been filed, and the city is under pressure from the Stream Control Commission to discontinue sludge disposal in this manner.

Fortunately there is a relatively deep ravine, on land about 3,000 ft. to the west of the plant, into which the sludge may flow by gravity and in which sufficient storage volume is available to hold the solids for 20 years. Work is now in progress which will lead to the construction of a sewer to this area and to the construction of the necessary lagoons for ponding. It has been proposed that, later, the overflow from these ponds may be returned to the plant for reuse.

Distribution Problems

It was pointed out above that the construction of a single plant on the west rim of the bowl would necessitate further provision for the distribution of the water supply to the opposite side of the city during periods of maximum demand.

To meet a maximum demand of 20 m.g.d., there were available only four 16-inch mains. Three of these mains lead to much lower ground and would draw heavily on the reservoir but the fourth terminated in a residential district $2\frac{1}{2}$ miles southeast and only 30 lb. below the static level of a full reservoir. The money was not available to provide an adequate supply line into the southeastern area and an elevated storage tank had been tried and abandoned. The plan adopted was to install booster pumps in the filter plant of sufficient capacity to force up to 5 m.g.d. through a 16-inch main to the east, for about three miles, and maintain a residual pressure of 30 lb. at the end, and an equal amount through a similar main leading to the west and south. The maximum head required was 130 ft. Two horizontal centrifugal pumps, driven by variable speed motors, were installed for this purpose. The pressure at the end of the main

to the east is transmitted back to the plant through telephone cables and recorded on a chart near the regulating drum controllers of these pumping units. The operator, by inspection of the chart, manually adjusts the pump speed to meet the pressure requirements. Through two seasons of operation, this procedure has proven satisfactory.

Architectural Treatment

The site of the new softening plant is the highest ground in the vicinity of Ann Arbor, and is surrounded by land that may be ex-

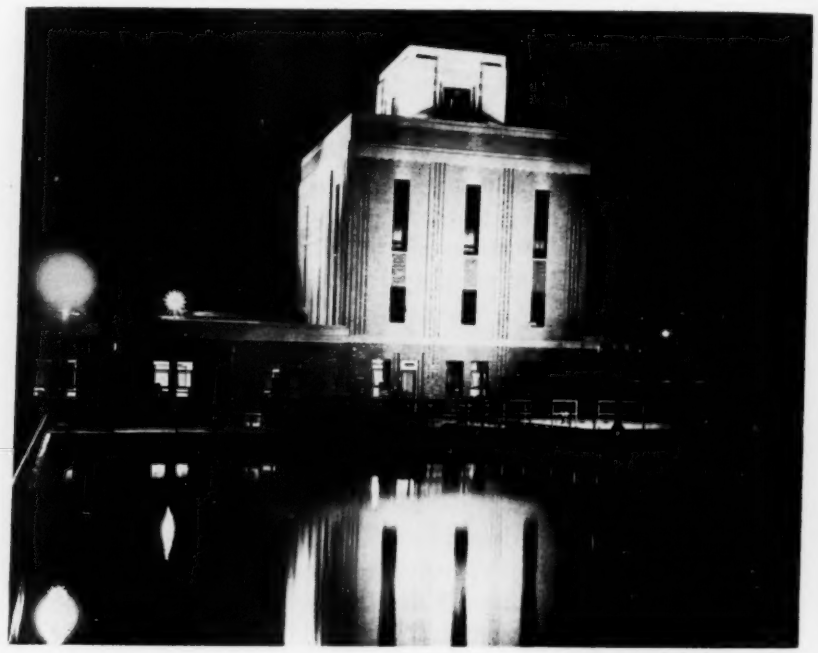

FIG. 4. Night View Showing Flood Lighting Effects

pected, in time, to develop into a high-class residential district. The area overlooks the Huron River Valley to the north, and the business portion of the city and University campus to the east. With this aspect in mind, it was desired that a structure be provided with suitable architecture and landscaping, but without extravagance.

The particular architectural features to be noted are: the brickwork that is shaded from a deep dark red at the base course to a tangerine at the top of the tower, the tower which is flood-lighted (Fig. 4) by clusters of lights on the laboratory and filter room roofs, and

the penthouse which is more brightly lighted from the top of the tower. The result is an incandescent effect from the distance and an interesting landmark at night from the highways and airways approaching the city.

On the inside of the building, the floors and walls of the pump room in the basement and all of the main floor, lobby, laboratory, offices, and filter room are lined with tile, but only in the lobby, vestibule, and filter room floor were any decorative effects introduced. In addition, attractive aluminum railings are provided around openings, and attention was given to interior lighting effects. The additional cost of the tile work over monolithic concrete painted walls and floors was not a large item in the cost, and was thought justified from the standpoint of reduced maintenance and the advantages of increased attractiveness to visitors.

The tower of the building, accessible through easy stairs, is an interesting observation point for Ann Arbor and vicinity.

The plant proper, exclusive of raw water mains, cost $422,582.00. The cost of operation and maintenance, exclusive of power, was, in 1939, $33,398.52, or $19.35 per mil. gal. treated.

This project was designed and the construction supervised by Ayres, Lewis, Norris and May, Consulting Engineers, Ann Arbor, Michigan. The writer is pleased to have this opportunity to acknowledge the valuable assistance given by Arthur B. Morrill during the preliminary studies, and by Eugene A. Hardin and James E. Wark in the preparation of the plans and specifications. Also, great credit is due to Harry E. McEntee, Supervising Chemist, for the excellent operating results that have been achieved to date.

Operation of the Ann Arbor Softening Plant

By Harry E. McEntee

THE water supply for the City of Ann Arbor is obtained from a series of wells and, in cases of emergency, from the Huron River. Results of analyses of composite samples of the water from the wells and the river are shown in Table 1. The standard method of operating the softening plant involves series flow. At such times as repair of the mechanical equipment or other emergency measures are necessary, however, the plant may be (and has been) operated with parallel flow during the dewatering of different portions of the regular equipment. There is, in fact, very little difference in the quality of the effluent resulting from the two types of flow, the only change being that the filters have to remove a greater amount of suspended solids with the parallel flow arrangement.

During the past year, there have been the opportunities to operate under four different methods: (1) conventional, (2) split treatment, (3) split treatment and return of primary sludge, and (4) split treatment and return of secondary sludge. On the flow sheet (Fig. 2) these different methods may be followed in the succeeding discussion.

Conventional Treatment

1. *Aeration:* Raw water is raised a distance of 200 ft., by high lift pumps, to a cascade aerator.

2. *First Rapid Mix:* Pebble lime, slaked with water to form milk of lime and soda ash, is added to the water at the first rapid mix, though this addition may also be made at the second mix when necessary. In the first mix, the added chemicals are rapidly and evenly dispersed throughout the water, which flows into the primary flocculation basin.

A paper presented on September 13, 1940, at the Michigan Section Meeting, Ann Arbor, by Harry E. McEntee, Supervising Chemist, Water Softening Plant, Ann Arbor, Mich.

3. *Primary Flocculation:* The chemically treated water flows transversely past three flocculating paddles, which stir it gently. In the basin, the first chemical reactions (due to the addition of lime and soda ash) are nearly complete, as shown by the following equations:

$$CO_2 + Ca(OH)_2 \rightarrow \mathit{CaCO_3} + H_2O \quad \text{(a)}$$
$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow \mathit{2CaCO_3} + 2H_2O \quad \text{(b)}$$
$$Mg(HCO_3)_2 + Ca(OH)_2 \rightarrow MgCO_3 + \mathit{CaCO_3} + 2H_2O \quad \text{(c)}$$
$$MgCO_3 + \text{Excess } Ca(OH)_2 \rightarrow \mathit{Mg(OH)_2} + \mathit{CaCO_3} + \text{Excess } Ca(OH)_2 \quad \text{(d)}$$
$$MgSO_4 + \text{Excess } Ca(OH)_2 \rightarrow \mathit{Mg(OH)_2} + CaSO_4 + \text{Excess } Ca(OH)_2 \quad \text{(e)}$$
$$\left.\begin{aligned} CaSO_4 + Na_2CO_3 &\rightarrow \mathit{CaCO_3} + Na_2SO_4 \\ CaCl_2 + Na_2CO_3 &\rightarrow \mathit{CaCO_3} + 2NaCl \end{aligned}\right\} \quad \text{(f)}$$

FIG. 1. Laboratory

4. *Primary Sedimentation:* In the primary sedimentation basin, the compounds (italicized in the above equations), $Mg(OH)_2$ and $CaCO_3$, being relatively insoluble, are free to settle to the bottom of the basin, and are removed by sludge collectors to a receiving hopper. From this point the sludge can be returned to the rapid mix or be discharged to the river. It will soon flow to the drying beds, now under construction.

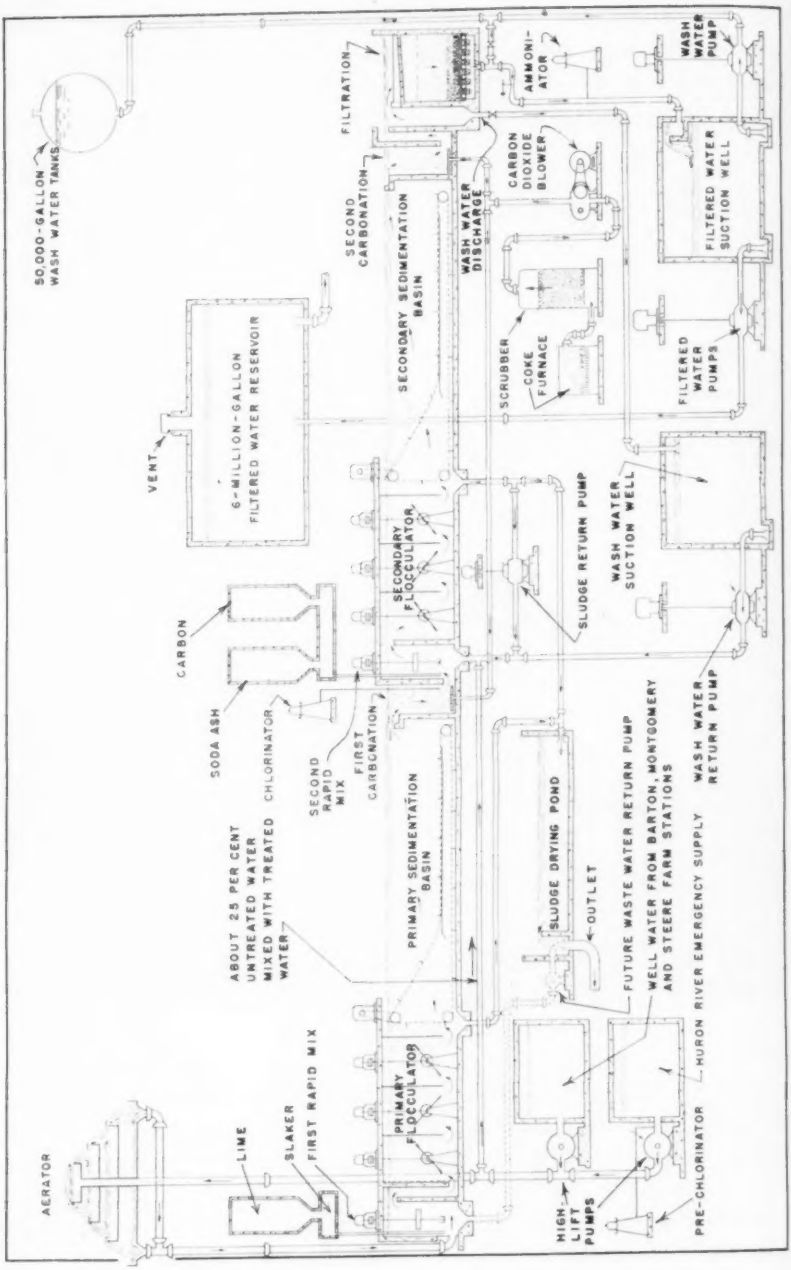

FIG. 2. Flow Diagram

5. *Carbonation:* Here, any excess caustic alkalinity (for the most part due to soluble calcium hydroxide) is converted to insoluble calcium carbonate by the addition of carbon dioxide (manufactured by burning coke):

$$C + O_2 \rightarrow CO_2 \quad \text{(g)}$$
$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O \quad \text{(h)}$$
$$CO_2 + Mg(OH)_2 \rightarrow MgCO_3 + H_2O \quad \text{(i)}$$

The $MgCO_3$ formed is soluble and will not settle, but remains in solution.

6. *Second Rapid Mix:* Here, any coagulant or carbon added is rapidly dispersed through the water.

7. *Second Flocculation:* Calcium carbonate, formed in the first carbonation, or chemicals which are added, is stirred gently with the water.

TABLE 1

Analyses of Composite Samples of Well and River Waters

	MINIMUM	MAXIMUM
	p.p.m.	*p.p.m.*
Alkalinity as $CaCO_3$	250	315
Free CO_2	8	12
Magnesium	22	30
Iron	0.8	1.0
Non-Carbonate Hardness	60	80*
Total Hardness	310	395
Hydrogen Sulfide	0	0.8
Turbidity	0	20
Threshold Odor	7	22
Bacterial Count—37°C.	25	2,000
Esch. coli Index	0	10,000

* Mostly sulfates.

8. *Secondary Sedimentation:* In this basin, most of the calcium carbonate, carbon, or other suspended matter settles out. The material is removed, by sludge collectors, either to the sewer or to the rapid mix.

9. *Recarbonation:* The water can be recarbonated after it passes the secondary sedimentation basin and before it reaches the filters.

10. *Filtration:* Finally, the water, which still contains suspended matter, calcium carbonate, carbon, etc., is filtered. The spent wash water from the filters is returned to the sedimentation basins, where the suspended solids are removed and the water reclaimed.

TABLE 2

Methods of Operation

UNIT OPERATION NO.	STATIONS	FLOW CYCLE	1 CONVENTIONAL	2 SPLIT TREATMENT	3 SPLIT TREATMENT AND RETURN OF PRIMARY SLUDGE	4 SPLIT TREATMENT AND RETURN OF SECONDARY SLUDGE
		Total Alk. as $CaCO_3$	294	309	314	241
		Free CO_2	10	9	9	10
		Magnesium	27.6	29	29.1	24.3
1	Aeration	Non-Carb. Hardness	60	73	62	78
		Total Hardness	354	382	378	319
		pH.	7.6	7.7	7.8	7.8
		Iron	.8	0	0	0
		Total Alk.	115	91	79	105
3	Primary Flocculation	CO_3 Alk.	39	32	34	35
		$(OH)_2$ Alk.	76	59	45	70
		Total Alk.	107	85	74	104
4	End of Primary Sedimentation	CO_3 Alk.	36	32	30	38
		$(OH)_2$ Alk.	71	53	44	66
		Total Alk.	86	88	74	103
5	End First Carbonation	CO_3 Alk.	84	34	30	37
		$(OH)_2$ Alk.	0	54	44	66
		Total Alk.	84	113	90	42
6	Second Rapid Mix	CO_3 Alk.	82	100	88	38
		$(OH)_2$ Alk.	0	0	0	0
		HCO_3 Alk.	2	13	2	4
		Total Alk.	55	66	72	36
8	End of Secondary Sedimentation	CO_3 Alk.	54	54	72	34
		$(OH)_2$ Alk.	0	0	0	0
		HCO_3 Alk.	1	12	0	2
		Total Alk.	53	64	70	36
9	End of Second Carbonation	CO_3 Alk.	20	48	68	32
		$(OH)_2$ Alk.	0	0	0	0
		HCO_3 Alk.	33	16	2	4
		Total Alk.	46	42	60	34
		CO_3 Alk.	10	26	60	32
		$(OH)_2$ Alk.	0	0	0	0
		HCO_3 Alk.	36	16	0	2
10	Filtered	Magnesium	8.4	9.7	16.5	8.2
		Non-Carb. Hardness	51	34	55	58
		Total Hardness	97	76	115	92
		pH.	8.5	9.3	9.3	9.3
		Iron	0	0	0	0

Split Treatment

When split treatment is practiced, recarbonation is discontinued, and a portion of the raw water is added to the treated water in the second mix. Here, the excess caustic alkalinity (present in the treated water) is converted to carbonate by the free and one-half bound carbon dioxide naturally present in the raw water.

Split Treatment and Return of Primary Sludge

This procedure is similar to the split treatment mentioned above, except that the primary sludge, which contains magnesium hydroxide and calcium carbonate, is also added to the water in the second mix.

Split Treatment and Return of Secondary Sludge

This procedure also closely parallels the simple split treatment except that the secondary sludge, which contains for the most part calcium carbonate and carbon, is also added to the water in the second mix.

Results from Conventional Treatment

Reference to Table 2, Column 1, will give operating data for the period during which conventional treatment was used. During this period soda ash was added to the first rapid mix. Results in the various operational phases were as follows:

Aeration (Operation 1): There is little reduction in carbon dioxide, because the carbon dioxide in the raw water is low initially.

Primary Flocculation (Operation 3): The total alkalinity, as calcium carbonate, shows a reduction of from 294 p.p.m. to 115 p.p.m. as the water leaves the basin. Of the total, 39 p.p.m. is calculated as carbonate alkalinity and 76 p.p.m. as hydroxide alkalinity.

Primary Sedimentation (Operation 4): There is a slight drop in alkalinity across this basin, probably because of the additional precipitation of magnesium hydroxide.

Carbonation (Operation 5): At the end of the first carbonation, carbon dioxide gas has been added, and the 71 p.p.m. caustic alkalinity originally present has been converted to carbonate alkalinity. Theoretically, at this point, there should be a total alkalinity of 107 p.p.m. The actual total, 86 p.p.m., represents a reduction (21 p.p.m.) which is probably due to the fact that the calcium carbonate formed and being agitated through the water removes some alkalinity.

Second Rapid Mix (Operation 6): Little change in the alkalinity occurs. Four parts per million carbon is added.

Secondary Sedimentation (Operation 8): The alkalinity is reduced 29 p.p.m. because part of the calcium carbonate formed by recarbonation settles in this basin.

Recarbonation (Operation 9): Carbon dioxide is added and 32 of the 54 p.p.m. of carbonate alkalinity, originally present, is converted to bicarbonate alkalinity. Practically no reduction in the total alkalinity is obtained in the first carbonation channel because of the small amount of calcium carbonate present there.

Filtration (Operation 10): The filtered effluent shows a reduction in total alkalinity of 7 p.p.m. which is probably caused by the addition of an insufficient amount of carbon dioxide gas in the recarbonation channel. The water is still unstable and contains a colloidal alkalinity which has plated out on the previous deposit of carbonate and on the grains of sand, as the water passed through the filter. If carbon dioxide had been added to the point where there would be no drop in alkalinity through the filters, the alkalinity of the filtered water would have been higher than 46 p.p.m. No doubt many softening plants are operated with a drop in alkalinity through the filters, not because of the economy obtained in using the filter sand as a softening agent, but because such operation is a necessity. In other words, from the time that the raw water enters the plant to the time the applied water goes to the filters there are two main problems: (1) the solubility of magnesium hydroxide and calcium carbonate, and (2) their precipitation. Even with ideal operating conditions, it is difficult to obtain a low constant alkalinity. Part of the magnesium and calcium remains in solution and will not crystallize out.* Where in this case there is a total alkalinity of 84 p.p.m., entering the second flocculation and sedimentation basins, theoretically the water should have a total alkalinity of about 25 p.p.m. as it leaves the second sedimentation basin, and this cannot be obtained because of the colloidal alkalinity.

Results from Split Treatment

Carbonation (Operation 5): Reference to Table 2, Column 2, will reveal that at the end of the first carbonation channel, the alkalinity

* This unprecipitated magnesium and calcium will hereinafter be termed "colloidal alkalinity."

is reduced, by precipitation, from 309 p.p.m. to 88 p.p.m. There is practically no change in the alkalinity in the first carbonation basin, because no carbon dioxide is added.

Second Rapid Mix (Operation 6): After the second mix, the alkalinity shows an increase to 113 p.p.m. Of this total, 100 p.p.m. is in carbonate form and 13 p.p.m. in bicarbonate, because the carbon dioxide and bicarbonate alkalinity present in the raw water, and which has been added to the treated water, is converted to a carbonate alkalinity.

Secondary Sedimentation (Operation 8): At the end of sedimentation, the total alkalinity is reduced 47 p.p.m. The reduction is caused by the precipitation of some of the carbonates. The alkalinity, however, is still high because of the colloidal alkalinity still in solution.

Filtration (Operation 10): The final effluent shows a reduction of 22 p.p.m. in total alkalinity. This change after filtration is caused by the crystallizing out of the colloidal alkalinity on the filter media.

Results of Split Treatment and Return of Primary Sludge Containing Magnesium Hydroxide

Carbonation (Operation 5): Reference to Table 2, Column 3, discloses that at the end of the first carbonation, the alkalinity has been reduced to 74 p.p.m., by precipitation. No carbon dioxide is added in this operation.

Second Rapid Mix (Operation 6): After the second mix, the total alkalinity, mostly carbonate, is 90 p.p.m., an increase of 16 p.p.m. One thing to consider in the return of a magnesium hydroxide sludge with raw water is the possibility that magnesium carbonate may be formed as in the equation:

$$Ca(HCO_3)_2+Mg(OH)_2 \rightarrow CaCO_3+MgCO_3+2H_2O \quad \text{(j)}$$

The $MgCO_3$, being soluble, would not precipitate and would, therefore, cause a high alkalinity.

Secondary Sedimentation (Operation 8): Only 18 p.p.m. reduction in alkalinity is shown after sedimentation, but the water in the basin is the clearest that has ever been observed in Ann Arbor.

Recarbonation (Operation 9): No carbon dioxide is added in the recarbonation, when this method of operation is followed.

Filtration (Operation 10): The filter effluent shows a reduction in alkalinity of 10 p.p.m. The magnesium, however, is about 6.8 p.p.m. higher than when the split treatment method is used.

Results of Split Treatment and Return of Secondary Sludge Containing Mostly Calcium Carbonate

Carbonation (Operation 5): Reference to Table 2, Column 4, shows that, from the aerated water to the end of the carbonation basin, the alkalinity is reduced to 103 p.p.m. by precipitation. No carbon dioxide is added.

Second Rapid Mix (Operation 6): After the second mix, the total alkalinity shows a reduction from 103 to 42 p.p.m., because of the addition of calcium carbonate sludge. This is an important result which will be further developed in a later section of this paper.

Second Sedimentation (Operation 8): At the end of the second sedimentation basin a slight reduction in alkalinity, caused by the additional stirring of calcium carbonate sludge in the water in secondary flocculation, is shown.

Recarbonation (Operation 9): No carbon dioxide is added in recarbonation when this method is used.

Filtration (Operation 10): Practically no reduction in hardness takes place in the filters—a good indication that the water is relatively stable.

Recapitulation of the "Split Treatment and Return of Secondary Sludge" Method of Water Softening

In order to obtain optimum results in the reduction of carbonate hardness, it is imperative that the magnesium be reduced to as low a concentration as possible. To obtain the maximum magnesium removal, we follow the law of mass action by increasing the hydroxyl ion, that is increasing the causticity to an excess, so that the maximum amount of magnesium hydroxide is produced and will precipitate (Equations (d) and (e)). Referring to the data of the above method, and starting at the end of the carbonation channel (Operation 5), we observe that the total alkalinity is 103 p.p.m., 37 as carbonate and 66 as hydroxide. The problem then becomes one of converting the 66 p.p.m. of hydroxide alkalinity—soluble—to calcium carbonate which, being relatively insoluble, will precipitate.

If carbon dioxide gas is added for this purpose (Equations (h) and (i)), the carbon dioxide will convert the 66 p.p.m. hydroxide alkalinity to 66 p.p.m. carbonate alkalinity, leaving the total alkalinity of 103 p.p.m. as carbonate. From this point to the water

going on the filters, the precipitation of the carbonates formed must be depended upon to lower the alkalinity. It is to be remembered, however, that magnesium carbonate is soluble and theoretically does not precipitate. Likewise some of the calcium carbonate will not precipitate.

In the raw water we have free carbon dioxide and a bicarbonate alkalinity, containing bound carbon dioxide. Adding this raw water to the treated water, containing the hydroxide alkalinity, which is to be converted to carbonate (the familiar split treatment), we may make the following calculations:

1. Given a total alkalinity of 103 p.p.m., phenolphthalein alkalinity of 84.5 p.p.m. and causticity, 66 p.p.m., in terms of calcium carbonate, in the treated water.

2. Given 241 p.p.m. (in terms of calcium carbonate) of bicarbonate alkalinity in the raw water.

3. Given 10 p.p.m. of free carbon dioxide in the raw water.

4. Convert the carbon dioxide over to the equivalent of calcium carbonate; that is, $\frac{100}{0.44} = 2.275$, which is the conversion factor.

5. Then, (241) + (2.275) 10 = 263.75 p.p.m. of total alkalinity in the raw water, all in terms of calcium carbonate.

6. Alkalinity as calcium carbonate in the raw water = alkalinity as calcium carbonate in the treated water.

7. $\frac{66 \times 1{,}000{,}000}{263.75} = 250{,}000$ gal. raw water required to be added to 1,000,000 gal. of treated water, where all the alkalinity will be converted to carbonate.

Theoretically, all the total alkalinity of the mixed sample, at the moment of combination, should be greater than 103 p.p.m. because of the additional alkalinity formed by the addition of raw water. Also, the combined waters should have an alkalinity where twice the phenolphthalein alkalinity equals the methyl orange alkalinity (2P = M. O.):

1. $1.00 \times 103 = 103$
   $0.25 \times 263.75 = 66$
   169

2. $\frac{169}{1.25} = 135$ p.p.m. total alkalinity

3. Phenolphthalein alkalinity in the treated water is 84.5 p.p.m.
4. Then, $1 \times 84.5 = 84.5$
   $0.25 \times 00.0 = \underline{00.0}$
   84.5
5. And, $\frac{84.5}{1.25} = 67.5$ p.p.m. phenolphthalein alkalinity.
6. 2 P = M.O.
7. 2 (67.5) = 135 p.p.m. total alkalinity.

This mixed water now contains a supersaturated solution of colloidal carbonate. Before any sludge is added let us consider the following experiment. (Fig. 3)

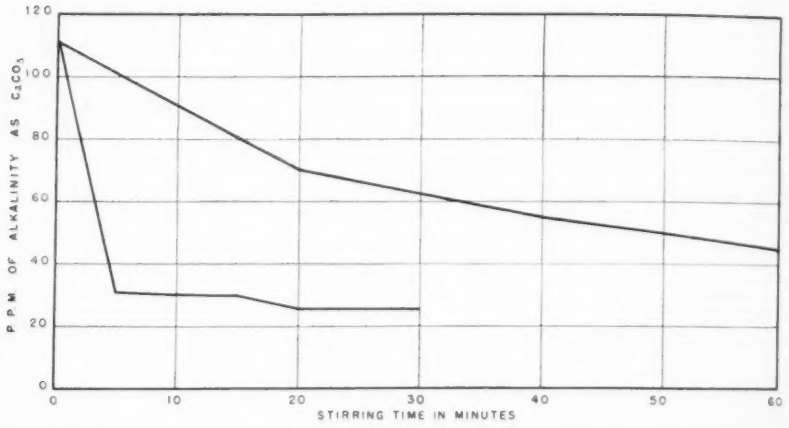

FIG. 3. Results from adding 250 ml. raw water, having a total alkalinity of 237 and free CO_2 of 10 p.p.m., to 1,000 ml. treated water, having a total alkalinity of 69 and a caustic alkalinity of 35 p.p.m. The top curve shows a reduction with stirring, nothing added. The bottom curve shows a greater reduction in a shorter period by adding 5 grams of $CaCO_3$ and stirring.

By preparing the sample, as described, the following observations are to be made:

1. If the sample is filtered immediately after the raw water is added to the filtered water, the alkalinity is 107 p.p.m.
2. Therefore, particles of colloidal dimensions must have passed through the filter paper.
3. The filtered sample is sparkling clear; no particles in suspension are visible.
4. By stirring the sample, a grayish color, evenly dispersed

throughout the liquid and caused by the formation of particles of calcium carbonate, may be observed after 7 min.

5. At 15 min., particles of sediment may be observed.

6. At 20 min., there is little change in the appearance of the sediment. By filtering and determining the alkalinity of a small portion of the sample, however, a reduction of 37 p.p.m. is to be observed.

7. At 40 min. stirring, the particles of sediment are much larger and have the appearance of the familiar alum floc. By filtering a portion of this sample, a further reduction in alkalinity is observed.

8. At 60 min., there are fewer particles, but they are much larger. Filtration shows still further reduction in alkalinity.

9. A microscopical examination of the precipitate at 430 magnifications reveals an aggregation of small crystals of indefinite shape—rounded, square, oblong, pointed—which are clinging together.

10. By moving the mechanical stage back and forth rapidly we observe that single crystals, or crystals attached together in pairs, when they come in contact with other crystals, will cling together tenaciously.

From the above observations the following conclusions may be drawn:

1. Stirring a supersaturated solution of water, containing colloidal alkalinity due to calcium carbonate, will cause the particles to grow from a sub-microscopical state, to a larger substance in the macroscopical state.

2. This growth of particles will cause their precipitation and also will allow them to be removed by filtration to reduce the alkalinity.

By taking a sample of water, as used in the above experiment, and adding 5 grams of calcium carbonate, then stirring at the same rate (80 r.p.m.) the following observations may be made:

1. In 5 min., the alkalinity has been reduced to 31 p.p.m.

2. At 20 min., the alkalinity has been reduced to 25 p.p.m. In other words, the alkalinity has been reduced to the theoretical.

3. It requires about 20 min., using the Ann Arbor equipment, to get the maximum reduction in alkalinity.

We have learned from the above experiment that, by inoculating the solution with calcium carbonate, there is a tremendous removal of colloidal alkalinity in a matter of minutes. No doubt this reduction starts immediately after the calcium carbonate is added to the solution.

Knowing that calcium carbonate, which has a negative charge,

will remove colloidal alkalinity from water, we may try the familiar stability test (Fig. 4). By using this test on a sample of water, as described, and employing various materials, we make the following observations:

1. Fine sand and calcium carbonate are about equal in the removal of colloidal alkalinity.

2. Activated carbon will remove alkalinity, but not quite as well as calcium carbonate and sand.

3. Magnesium hydroxide does not remove colloidal alkalinity.

4. Activated carbon having a neutral to a positive charge will

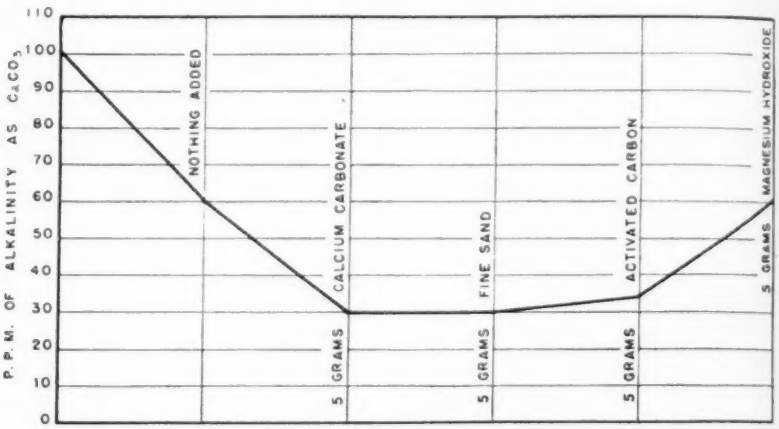

FIG. 4. Results of (1) adding 200 ml. raw water, having a total alkalinity of 275 p.p.m. and free CO_2 of 10 p.p.m., to 1,000 ml. treated water, having a total alkalinity of 99 and a caustic alkalinity of 61 p.p.m.; and (2) adding the substances mentioned and stirring for 20 min. at 80 r.p.m.

remove alkalinity nearly as well as calcium carbonate or silicon dioxide which have negative charges.

5. Magnesium hydroxide, having an amorphous jelly-like consistency, does not seem to remove the colloidal alkalinity.

6. It appears that any relatively insoluble particle having a hard solid surface will remove colloidal alkalinity, when it is used under the proper conditions.

From observations to date it would be very convenient to make the statement that this reduction in colloidal alkalinity is due to the fact that particles of calcium carbonate added to the supersaturated solution absorb colloids on their surface, thereby removing the

alkalinity. Much more must be learned, however, before such a statement may be made.

The most important factor is that there seems to be a quantitative correlation between the quantity of colloidal alkalinity removed and the quantity of particles added. Adsorption probably is an important factor. If this is true, the size of the particles, and the velocity in which these particles are stirred in a supersaturated solution, may reveal interesting data. Another factor worth serious consideration is the crystallization and aggregation of particles through the means of mechanical agitation. Work is now being done along both these lines.

One observation which is interesting is the size that is sometimes attained by these particles. Pebbles of material as large as a half-inch in diameter have been removed from the bottom of the mixing well. These particles are hard, resembling small pieces of gravel. By breaking one of the pebbles, a series of white, black, and gray rings may be observed. The black and gray rings, no doubt, represent the periods when a greater or less amount of activated carbon was used for taste and odor removal.

At Ann Arbor excellent results are attained with $1\frac{1}{2}$ per cent settleable solids which are continuously returned to the second rapid mix. Soda ash is purposely added to the second mix because of the calcium carbonate which is precipitated in the reaction (Equation (f)).

The freshly precipitated carbonate, from the addition of soda ash, plus the freshly precipitated carbonate, from the addition of raw water, continuously forms a surplus of available sludge to continue the cycle for this method of treatment. Wash water, with its residue of sludge, is also returned to the second rapid mix.

Referring to Table 2, in a comparison of the drop in alkalinity between the second mix and the end of the secondary sedimentation on all four methods of operation, it is interesting to note that in Method 4 (return of secondary sludge) there is only a 6-p.p.m. drop in alkalinity. It is not necessary, therefore, to depend on a 5-hour retention time for the precipitation of alkalinity, because this condition has been achieved in 3.7 min. There is, however, a turbidity of about 5 p.p.m. in the applied water, due to fine particles of sludge; but this appears to be an advantage because the fine sludge seems to act as a "filter aid." It is common practice in the chemical industry to use diatomaceous earth to form a "pre-coat" on cloth filters.

Perhaps one of the physical advantages of calcium carbonate is that it is not as compressible as the usual coagulants, such as aluminum hydroxide, ordinarily used in water purification. Also, as the particles of calcium carbonate settle on and in the filter surface, they probably form a mat with a larger void space than obtained with alum coagulation, but sufficiently small to entrain fine turbidity.

The Ann Arbor plant obtains filter runs of 156 hr. with an initial loss of head of 1.0 ft. and a final loss of head of 4.0 ft. at a 125–m.g.a.d. rate. Without the addition of any coagulant (this being the way the plant is operated), the turbidity on the finished water is only 0.2 p.p.m. If the filters are put in interrupted service and they are again started, however, a turbidity of 2 p.p.m. is observed for the first 5 min. of operation. Then the water clears back to normal.

After two years of operation the Ann Arbor filters appear to be in excellent condition. The first 10 in. of sand has a black appearance, due to carbon, but below this depth it is perfectly clean.

Due to the addition of raw water to the second mix, there is about 25 per cent more magnesium present in the filtered water than would result from conventional softening. By using the split treatment and return of secondary sludge method, however, the following results are obtained:

1. The plant can produce a water with a low constant carbonate alkalinity.
2. The water is stable.
3. Recarbonation is not necessary.
4. Caustic alkalinity is not wasted, as it is used for additional softening.
5. A substantial saving in the cost of chemicals and electric power is effected. Only about 80 per cent of the amount of lime, which would be used in conventional treatment, is necessary, and this factor together with the other economies makes the total average saving per million gallons $2.21—$1.26 on lime, $0.45 on coke and $0.50 on electric power.

Another advantage in using the split treatment return of secondary sludge method is the elimination of the operating difficulties experienced by using recarbonation. The raw water is the means of recarbonation and the only mechanical equipment required is a valve to regulate the amount of raw water to be added to the treated water in a well having good mixing facilities. The next and most important step of all is to be able to add a sufficient amount of calcium

carbonate sludge to this mixing well to stabilize the water. After a sufficient amount of sludge is added, a stable water of a low alkalinity, containing both a carbonate and a bicarbonate alkalinity if desired, can actually be produced.

Figure 5 explains this statement more clearly. In this experiment, six samples were set up, each containing 1,000 ml. of treated water having the following analysis: methyl orange alkalinity, 96; phenolphthalein alkalinity, 78; caustic alkalinity, 60; and carbonate alkalinity, 36.

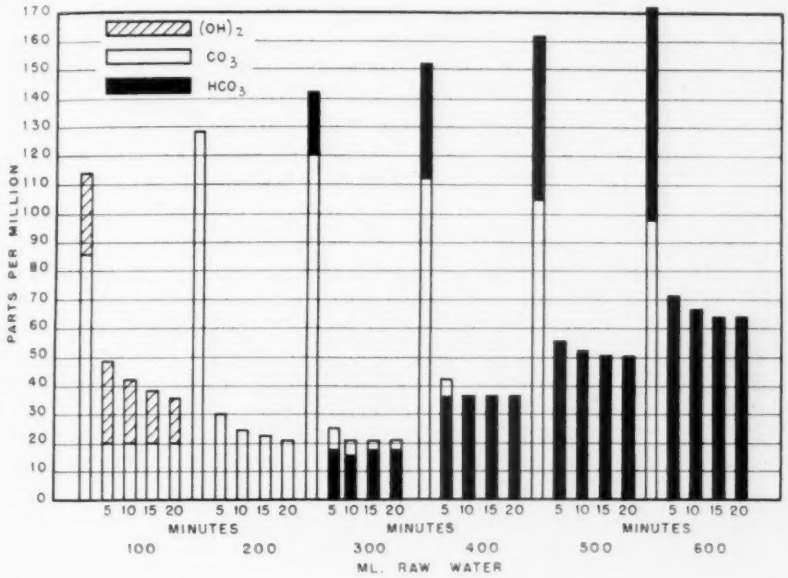

FIG. 5

To each sample there was added from 100 to 600 ml. of raw water having the following analysis: methyl orange alkalinity, 270; and free carbon dioxide, 10.

To each sample was then added five grams of calcium carbonate. All six samples were stirred at 80 r.p.m. The alkalinities were determined at intervals from 5 to 20 min.

The bar on the left of each sample denotes the theoretical alkalinity which should be present in each sample. The analysis of this bar diagram reveals some interesting observations:

1. It requires 20 min. to obtain a maximum reduction in alkalinity under the conditions of the experiment.

2. Therefore, it would be good practice for the plant to use this standard for the future determination of stability.

3. There is a reduction of about 50 per cent in causticity in the sample to which 100 ml. of raw water was added.

4. The sample, to which 200 ml. of raw water was added, containing all carbonate alkalinity, has the maximum reduction which is to be expected.

5. In all the succeeding samples, the residual and the initial bicarbonate alkalinity are nearly the same.

6. In the samples which contain a carbonate and a bicarbonate alkalinity, all of the carbonate will be removed when a sufficient amount of raw water has been added.

7. The split treatment return of secondary sludge is the most satisfactory method of water softening for the Ann Arbor supply.

Operation Difficulties

Recarbonation: The manufacture of carbon dioxide of a definite percentage and showing a constant straight line on a graphic instrument is a particularly difficult operation for several reasons:

1. Carbon content of the coke will vary.

2. A thick layer of live fuel is most desirable. When fresh fuel is added, however, there is a drop in combustion, and drafts must be opened to meet the condition. When the fresh fuel is ignited, the increase in combustion requires further regulation of drafts. Finally when the fire needs cleaning, combustion again increases, and drafts again must be regulated. It has been found that, even with a 30-minute interval between furnace inspections, it is very difficult to obtain satisfactory results.

3. Some carbon dioxide blowers have very little clearance between the impeller and casing and will "freeze" if shut down even for an hour. This freezing is probably due to the carbon, iron, and corrosive moisture from the carbon dioxide which has a chance to form a bond between the impeller and the casing. It has been found good practice, therefore, to turn the blower over every 30 min. for the first eight hours after a shut down.

4. Care must be taken in shutting down recarbonation equipment which has been working under a pressure. It is good practice to blow the carbon dioxide to the atmosphere to prevent the back

pressure, in reversing through the blower, from forming a vacuum which will suck sludge into the carbonation grids.

5. It is difficult, when feeding two rates of flow simultaneously, to regulate one flow without affecting the other. For instance, with a 100-cu.ft. per min. flow to the first carbonation line and an 80-cu.ft. per min. flow to the second carbonation line, simultaneously, from one blower, if the 100-cu.ft. per min. flow is cut down to meet a change in causticity going into the first carbonation channel, there will be an increase in flow above 80 cu.ft. per min. into the second carbonation channel.

Under the assumption that carbonation is properly adjusted to convert the causticity in the first channel to carbonate and the carbonate in the second channel to bicarbonate, an excess of carbon dioxide in the first channel will convert some of the carbonate to bicarbonate, which, being in solution, will not precipitate in the secondary sedimentation basin. Also, under this assumption, an excess of carbon dioxide in the second channel will convert an excess of carbonate to bicarbonate.

Under the same conditions, a deficiency of carbon dioxide will allow a caustic alkalinity, which will not precipitate in the secondary sedimentation, to be present in the first carbonation channel. A deficiency in the second channel would, in the same way, convert an insufficient amount of carbonate to bicarbonate alkalinity, thus leaving an unstable water which will permit crystallization on the filter media. Carrying this assumption through to the time when the caustic alkalinity reaches the second carbonation channel, we see that if the deficiency in the amount of recarbonation has been corrected to meet the condition at the previous time, this caustic alkalinity, now present, will then carry on through the filters.

This is an example of what actually occurs when there is a deviation in the correct amount of carbon dioxide required for maximum efficiency. It may also be appreciated what the figures on the reaction record would amount to—especially in plants where frequent alkalinity checks are taken at the important stations on a definite time schedule.

Lime Slaking: Pebble lime is purchased on the basis of an available calcium oxide of 90 per cent. Analyses of the lime, however, vary from 75 to 92 per cent. The variation is probably due, not to the raw product, but to the manufacture. Under-burning and over-burning of the lime are only one phase of a series of operating diffi-

culties which face lime manufacturers in their attempt to produce a high quality product.

By storing a series of shipments of lime of various analyses in the same bins, it is obvious that the quality of the lime being fed to the slaker will not be constant, and, therefore, the causticity at the primary flocculation will vary from that desired.

Coupling this condition with the difficulties experienced in recarbonation, and assuming that both occur simultaneously—which is common—we may appreciate some of the difficulty entailed in operating a water softening plant.

Much remains to be learned about the proper methods of slaking. We must know: what is the proper weight of water per pound of lime; what is the proper temperature to have in the slakers; and what per cent of unslaked lime is present in the milk of lime. These and many other problems associated with the control of a softening plant afford the operator an unending basis for interest and activity.

ABSTRACTS OF WATER WORKS LITERATURE

Key. **31:** 481 (Mar. '39) indicates volume 31, page 481, issue dated March 1939. If the publication is paged by issues, **31:** 3: 481 (Mar. '39) indicates volume 31, number 3, page 481. Material enclosed in starred brackets, ★[ ]★, is comment or opinion of abstractor. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.—Bulletin of Hygiene (British); C. A.—Chemical Abstracts; P. H. E. A.—Public Health Engineering Abstracts; W. P. R.—Water Pollution Research (British); I. M.—Institute of Metals (British).*

CORROSION AND CORROSION CONTROL

Preliminary Researches of the Action of Water on Copper Pipes. L. Tronstad and R. Viemo. J. Inst. of Metals (Br.). **66:** 17 (Jan. '40). While amounts of Cu as great as 2 mg./liter (2 p.p.m.) are stated to be non-toxic, amount of Cu picked up by water important because water containing Cu liable to cause localized corrosion of Fe pipes and Al utensils. Cu acts as an oxidation catalyst in accelerating destruction by detergents of peroxide type of textile fibers such as cotton and artificial silk. Cu also results in destruction of vitamin C during cooking. Cu content as high as 7.24 p.p.m. reported from water in new mains, with content down to 0.8 p.p.m. from same main 13 yr. later. This and other reports indicate Cu content of water decreases with age of pipe. Presumably due to formation of difficultly soluble film composed mainly of cuprous oxide, usually also containing a proportion of basic copper carbonates with Ca and Mg compounds also present. Corrosion behavior of Cu influenced by fact it may be either mono- or divalent, that cupric oxide is rather easily soluble, and that both oxides have little ability to form protective films. With drinking water, increase in oxygen content above a certain limit has less influence than increase in non-oxidizing acids; indicated by fact that only small amount of O required to bring about saturation of soln. with sparingly soluble cupric compounds. Mechanism of O action not exactly clear, may depend on depolarization of hydrogen at the metal surface or on a primary oxidation of Cu to cuprous or cupric oxide. In either case O consumed during process. Solubility of several Cu minerals and oxides in boiled distilled water detd. with and without CO_2 additions. Free CO_2 promotes solution of Cu minerals considerably. This holds for Cuprite (Cu_2O), Copper oxide (CuO), Malachite [$CuCO_3 \cdot Cu(OH)_2$], Azurite [$2\ CuCO_3 \cdot Cu(OH)_2$] and Atacamite [$CuCl_2 \cdot 3\ CuO \cdot 4H_2O$]. Amount of Cu dissolved in tap water from Cu pipes with a protective coating of corrosion product will increase in presence of aggressive CO_2. Dissolved O in drinking water promotes dissolution of Cu, even in pipes with stable films, owing to oxidation of cuprous to more soluble cupric compounds. Effect of bicarbonates, CO_2, hydroxyl ions, oxygen, time

and temp. experimentally detd. on water in 50 cm. inside diam., 500 cm. long, 99 cm. capac. and 785 cm.² surface area, 99.8%–99.9% pure Cu tubes in spirals and immersed in thermostatically controlled temp. bath. Tests made with tap water with following content: total solids, 47.5 p.p.m., Cl, 9.5, Fe, 0.07, dissolved O, 10.8, CO_2 combined, 8, aggressive CO_2, 4, and pH, 6.3. From 0.42 to 0.78 mg. Cu (ave. 0.60) per liter dissolved by this water in 24 hr. standing in tube. Additions of from 0.1 to 1.2 grams per liter (100 to 1,200 p.p.m.) sodium bicarbonate to this water increased amount of Cu dissolved in 24 hr. from 0.6 p.p.m. ave. for water alone to 1.0 p.p.m. for water containing 100 p.p.m. sodium bicarbonate and to 4.5 mg. Cu per liter for water with 1,200 p.p.m. sodium bicarbonate. The Cu dissolved also increased with addition of $Ca(HCO_3)_2$. Increase in CO_2 content of water resulted in increase in Cu

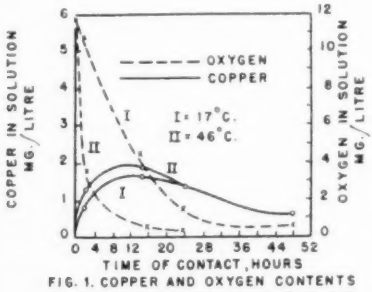

FIG. 1. COPPER AND OXYGEN CONTENTS OF TAP-WATER CONTAINING 7 MG. CARBON DIOXIDE/LITRE, AFTER STANDING FOR DIFFERENT PERIODS IN COPPER PIPES.

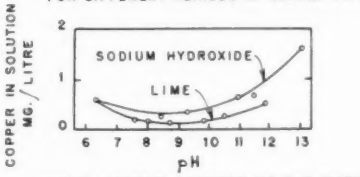

FIG. 3. COPPER CONTENT OF TAP WATER WITH ADDITIONS OF LIME AND SODIUM HYDROXIDE AFTER STANDING FOR 24 HOURS IN COPPER PIPES AT 18°C.

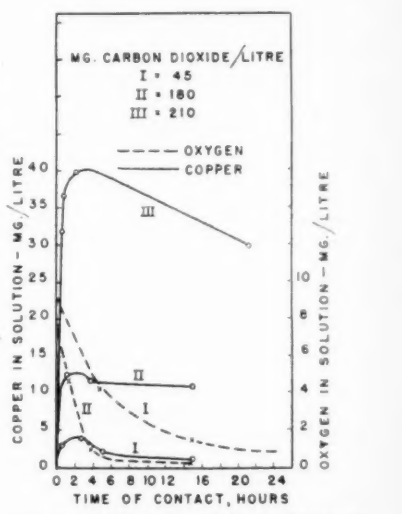

FIG. 2. COPPER AND OXYGEN CONTENTS OF TAP-WATER CONTAINING VARYING AMOUNTS OF ADDED CARBON DIOXIDE, AFTER STANDING FOR DIFFERENT PERIODS IN COPPER PIPES AT 20°C.

content after 24 hr. at 18°C., in agreement with increased solubility of malachite; considerable increase in Cu content occurred in water with 150 mg. and upwards of CO_2 per liter (see Fig. 2). On addition of hydroxyl ions from lime or sodium hydroxide, on increase in pH to between 8 and 9, amount of Cu dissolved decreases; further increase of pH, however, causes *increase* in Cu concentration. Use of lime results in lower Cu than when NaOH used (see Fig. 3). Effect of surplus O is relatively small. Max. Cu content, obtained in approx. 15 hr. in usual water, may be reached in 2–3 hr. in water containing CO_2. Rate of reaction appreciably increased with rise in temp. Decisive factors of corrosion process under slow rates of flow are O and aggressive CO_2 content of water, other constituents play minor roles. Correction of pH to 8.5, preferably with lime, method of control tentatively suggested.—*Martin E. Flentje.*

The Resistance of Copper to Soil Corrosion. H. G. TAYLOR. The Engr. (Br.) **169:** 156 (Feb. 16, '40); **169:** 176 (Feb. 23, '40). Experience has shown that fear of corrosion of buried copper gas and water pipes is unjustified. Museums contain many copper objects buried in soil for several thousands of years. Not suggested that such results can be obtained in any but favorable soils. Soil characteristics that can be taken as a measure of its power to corrode metals include: hydrogen ion content, amount of moisture, total acidity or alkalinity, nature and concentration of salts present, grain size, aeration of soil, and electrical resistivity. Known that low electrical resistivity, high acidity or alkalinity, or high moisture content are conducive to corrosion. Copper, like other metals, is susceptible to sulfide corrosion which may arise from cinders, from decaying vegetation, or from sewage. Most comprehensive tests on soil corrosion have been conducted and reported by U. S. Bureau of Standards. Similar tests, on smaller scale, now in progress in England. So far has been shown that in no case, except when soil was composed of cinders, was there more than a green coating on copper, whereas other metals were, in all soils, at least slightly pitted, and in some cases in bad condition. Some interesting accelerated corrosion tests, conducted by Southern Counties Gas Co. of Calif., have given following results: (1) corrosion of steel, expressed as loss of weight, is from 13 to 30 times greater than that of copper. (2) Corrosion of steel expressed as max. pit depth is from 74 to 250 times greater than that of copper. (3) By deduction from above, corrosion of copper is not only less, but is much more uniform than that of steel. More extensive series of tests conducted by Bur. of Standards has led to following conclusions: (1) Copper and alloys with high copper content were corroded slowly in most soils. Highest rates of corrosion of copper occurred in soils containing sulfides. (2) Rates of corrosion of all copper alloys were higher in cinders than in any type of soil tested. (3) Corrosion of copper and high-copper alloys was more nearly uniform over surface than was corrosion of ferrous materials in most soils. (4) Muntz metal dezincified in a considerable no. of soils and probably should not be exposed to severe soil conditions despite fact that in one case—a salt marsh—material was particularly satisfactory. (5) Rates of corrosion of copper and brass appeared to change less with time than did corresponding rates for ferrous materials. It is not known how many companies are using copper gas pipes at present but it is known that they are used to a very large extent by some. In '35, Southern Counties Gas Co. of Calif. had had nearly 9 yr. experience with underground copper pipes in many different soils. No case was found of appreciable corrosion and no case was found where accelerated corrosion of steel or cast iron pipes connected to copper pipes had occurred. For water distribution copper pipes were used in the U. S. before their adoption by gas companies. Use of copper service was made standard in '26, by Washington Suburban Sanitary District. Up to July '39, they had had no failures or maintenance trouble with any copper pipe used underground. Another company to standardize use of copper services is West Palm Beach Water Co. In '35, nearly all water companies in Calif. used some copper tubing for water services. In '26, Metropolitan Water. . . . Board of Sydney (Australia) decided that all replaced or new water services should be laid in solid drawn

copper. Up to July '38, 5,500,000′ of copper services were installed in Sydney and until June '39, only 9′ had become defective. In Melbourne (Australia) approx. 16,000 copper services have been laid. Copper for water pipes has been used in many areas in England. At Dundee, where copper pipes were first laid in '19, pipes underground for 18 years have shown no pitting. Inspections of dissimilar metal corrosion at junction of steel mains and copper services, made by Southern Counties Gas Co. disclose appreciable corrosion resulting from galvanic action occurs only in very corrosive soils. Where appreciable corrosion does occur it is close to connection between two dissimilar metals. Where surface of ferrous metal exposed to soil action is small, as compared with area of adjacent copper, rapid corrosion of former does occur in bad soils. When cast iron or steel pipes are to be connected directly to copper pipes, former should preferably not be protected by insulating wrapping unless completeness and permanency of wrapping can be assured.—*H. E. Babbitt.*

Study of the Attack of Lead Pipes by Acid, Alkaline and Distilled Water. Tamenaka Matubara. Mitt. Med. Akad. Kioto (Jap.) **25:** 186 ('39). In tests of action of waters on Pb, it was found that addn. of HCl, HNO_3, AcOH or NaOH in concns. varying from 0.001 *N* to 0.01 *N* increased amt. of Pb in soln.; addn. of H_2SO_4 or oxalic acid decreased amt. of Pb in soln. During tests in which water contained NaOH, H_2SO_4 or oxalic acid, concn. of Pb in water reached a max. and then decreased. pH values of acid liquids in contact with lead were increased; in solns. of NaOH, formation of slightly dissociated plumbites decreased pH value.—*W. P. R.*

Dissimilar Metal Couples. M. R. Whitmore and J. Teres. Heat Treating & Forging **25:** 5: 237 ('39). Corrosion of various aluminum alloys in seawater, when in contact with various steels and other metals both with and without protective coatings, is described. In contact with a chromium-molybdenum steel or brass, aluminum alloys were all severely corroded, but corrosion practically ceased when steel or brass was cadmium-plated; cadmium plating disappeared fairly rapidly in contact with anodized "24 ST Duralumin" alloy, but remained intact for long period in contact with "Alclad 24 ST," or copper-free alloys "52 S" and "53 ST." Stainless steel of 18:8 type caused much less corrosion of any of alloys than did other steels, brass, and Monel metal. Rivet corrosion was greatest with "24 ST." Impregnated fabrics of friction and Neoprene tapes, and coatings of zinc chromate primers, afforded considerable protection against corrosion produced by couple effect. Results were confirmed by reverse bend tests which also showed that "Alclad 24 ST" suffers very little deterioration in contact with most commercial alloys except steel and Monel metal; cadmium plating and insulating coatings practically prevent couple effects with all combinations tested. Potentials of dissimilar cells of 14 different combinations of metals and alloys with each of 8 different aluminum-base materials in *N*-sodium chloride containing 0.3% hydrogen peroxide are tabulated.—*I. M.*

Tank Analyses. An Investigation of the Causes of Rapid Pitting in Open Galvanized Water Tanks. W. M. PEIRCE. J. Amer. Zinc. Inst. **20:** 112 ('39). Spectroscopic analyses showed correlation between tin content of coating and rate of corrosion. Pitted samples showed 0.54–1.20% tin, and evenly corroded samples 0.02–0.28% tin.—*I. M.*

Farm Tank Tests. G. C. BARTELLS. J. Amer. Zinc. Inst. **20:** 101 ('39). Describes examples of pitting attack in galvanized water tanks used for field tests. Different materials were coated with different weights of zinc and exposed in different locations under similar conditions. Type of water was eliminated as primary factor.—*I. M.*

Pinhole Corrosion in Galvanized Watering Tanks. W. M. PEIRCE AND G. C. BARTELLS. Metals and Alloys. **11:** 2: 42 ('40). Abnormal form of corrosion in water tanks takes form of localized pitting and has been on increase in recent years. Investigation of samples from good and bad tanks showed remarkable relation between pitting and tin content of zinc. Not more than 0.28% tin was found in coating of any good tank and not less than 0.54% tin in coating of any bad tank. Suggested that tin remains as free tin in grain boundaries and accelerates corrosion of zinc, iron, and alloy layers. Onset of this type of corrosion trouble is possibly connected with increasing use of tin additions to galvanizing bath as means of controlling spangle.—*I. M.*

Sodium Hexametaphosphate as an Aid in the Control of Corrosion. OWEN RICE. J. N. E. W. W. A. **54:** 25 (Mar. '40) Use of sodium hexametaphosphate in amounts varying from 0.5 to 2 p.p.m. to prevent deposition of $CaCO_3$ also resulted in decrease in no. of red-water complaints. Chemical is adsorbed in thin film on metal and has ability to decrease rate of attack of oxygen on iron. Lab. exptl. device for demonstrating this property, using steel wool, described and illustrated. Time a factor in producing film, therefore advisable to start treatment off with higher dosage, 10–20 p.p.m., later dropping to 1-2 p.p.m. to maintain film.—*Martin E. Flentje.*

Prevention of Corrosion in Central Hot-Water Supply Systems. OTTO KRÖHNKE. Gas-u. Wasserfach (Ger.) **82:** 641 ('39). Use of copper pipes for hot-water systems has been forbidden in Germany. Aluminum is not satisfactory substitute; it corrodes in some waters, though not in others, apparently because of formation of protective film. Aluminum alloys are less resistant than pure aluminum and various suggested coatings proved unsatisfactory. Aluminum is corroded less by hot than by cold water. If aluminum hot-water heaters are used, entire hot-water system must be aluminum or non-metallic, to avoid bimetallic corrosion. Thin copper tubes with an outer plastic shell ("Kupremax") are permitted for certain aggressive waters. Steel piping and water heaters may be used if water is treated with sodium sulfite to remove oxygen, with sodium phosphate to form resistant coating, or with Magno to remove carbon dioxide and facilitate formation of protective coating. Simple methods for these treatments are available, especially use of solid blocks of a neutral mixture of sodium mono- and di-phosphate, with or

without sodium sulfite (K-C-S process). Other processes are being tested. To avoid rapid corrosion of heaters, water temp. should not exceed 60°C. and pressure variations should be avoided. Corrosion is much greater in pressure heaters than in those operated at atmospheric pressure. 47 refs.—*C. A.*

Corrosion Troubles in Heating and Hot-Water Systems. L. Kenworthy. J. Inst. Heating Ventilating Eng. **8:** 85: 15 ('40). Introductory account of general theory of corrosion is followed by discussion of practical problems associated with use of copper, iron, galvanized iron, brass, and lead in domestic and other types of hot-water installations. Effect of water-hardness is considered; presence of free carbon dioxide is particularly deleterious. Principal cause of failure of galvanized-iron hot-water tanks is deposit attack at base. Copper and galvanized iron should not be used together in same installation when water has cupro-solvent properties, since copper is precipitated on zinc and leads to rapid failure; 0.05 p.p.m. is sufficient to cause trouble.—*I. M.*

The Cathodic Behavior of Zinc Versus Iron in Hot Tap-Water. Gerhard Schikorr. Electrochem. Soc. Preprint, p. 147 (Sep. '39). Tests on galvanized steel pipe were conducted which showed that zinc in the coating behaved as cathode when submerged in hot tap-water. This cathodic behavior of zinc could, in general, be definitely established only at temp. above about 70°C. Experimental results tend to clarify a number of apparently unusual corrosion phenomena observed in practice with galvanized pipe used in hot-water service.—*I. M.*

New Viewpoints in Cold- and Hot-Water Corrosion. L. W. Haase. Korrosion u. Metallsch. **15:** 150 ('39) *and* Metals and Alloys. **10:** MA624 ('39). Describes investigation of causes of corrosion in public and domestic distribution systems. To avoid all corrosion, particularly in hot water systems, all pipes and fittings must be of same material. Local electric currents always cause corrosion when iron pipes are used with copper or brass fittings. Fairly good protection may be obtained by adding phosphate to the water; very dense and only slightly soluble layers are then formed inside pipes. Kind of phosphate must be selected carefully to suit particular water and must be added in sufficiently small quantities or no protective layer will be formed. Filters may produce local currents and so cause corrosion.—*W. P. R.*

Methods for Estimating the Corrosivity of Soils. K. H. Logan and E. A Koenig. Gas **16:** 1: 19 ('40). 8 methods were used to evaluate corrosiveness of soils: (1) soil resistivity (Shepard resistivity meter); (2) soil resistivity at moisture equiv.; (3) soil acidity; (4) acidity-resistivity test; (5) Columbia rod test; (6) Putnam test; (7) nipple-and-can test; and (8) Denison electrolytic test. Ave. results of tests were plotted against pit depths. Resulting graph did not show great deal of difference in degree of correlation of results of most of tests with pit depth. All methods show, in very general way, corrosiveness of soil samples, but whenever several test results having same value were obtained, widely divergent pit depths were associated with them. Appears

to be no fixed relation between results of tests and max. pit on joint of pipe nearest sample tested.—*C. A.*

Outside Corrosion of Pipes in a Distribution System. OTTO HANNEMANN. Gas u. Wasser. **83:** 229 (May 18, '40). Leakage occurred in distribution system after nearly 20 yr. of service in sections lying in valley bottoms. Pipes showed some pitting with deep soft spots containing material of only 52.7% Fe and much graphite. Hydrogen sulfide odor was considerable on uncovering pipe. Analysis showed that soil contained only traces of sulfate and sulfide. Ground water, however, was highly mineralized and rich in $CaSO_3$ and $MgSO_4$. Sulfate content may come from some pyrite in loam, in neighborhood, which oxidizes near surface, forming $FeSO_4$ and H_2SO_4. This may form gypsum but also attacks pipes. Sulfate content in ground water of pipe ditch of 250 p.p.m. may be dangerous to pipe. Damaged pipes were replaced and surrounded by ground limestone. Furthermore trench was drained in low sections.—*Max Suter.*

The Joint Corrosion Committee for Electrolysis Mitigation. M. W. GHEN. Edison Elec. Inst. Bul. **8:** 231 (May '40). In substructure very essential that possibility of damage from corrosion and stray current electrolysis be carefully scrutinized. Metallic substructures, buried in earth, subject to number of corrosion sources, principally "stray current", electrolysis, soil action and local galvanic action between dissimilar metals in suitable electrolyte. Most serious "stray currents" from street railways, rail used as a return path, current flows through rail and contacting earth and conducting substructure in earth may offer a return path. Mitigative steps must be taken to protect conducting substructure where current leaves it. Article has figures showing types of protection. One method is copper drainage cables connected from substructure to be protected to station-negative bus, to change direction of current flow between substructure and rail in positive area. Another method is extended negative system consisting of a number of return cables, tapping rails and also draining portion of substructure. Negative resistor or rail resistor type increases rail potential above ground and insures definite current flow toward substructures in vicinity of substation. For protection to pipe lines, bituminous coatings and wrappings are used where bad soil or galvanic conditions are known to exist. Mitigation of electrolysis and corrosion damage requires efforts of experienced engineers.—*Samuel A. Evans.*

Earthing to Water Pipes. ANON. Wtr. and Wtr. Eng. (Br.) **42:** 71 (Mar. '40). Since American Research Com. on Grounding was organized in '36, its technical subcommittee has made field investigations in situations where troubles had developed. Com. has also been in contact with Inst. of C. E. Research Committee's subcommittee which is making a similar study in Great Britain. British com. has made no more progress than American. Same difficulties have been experienced. Has been found that under normal operating conditions water pipes regularly carry a.c. ranging from 25 to 75% of house load. No. of cases of serious shock, and one of a serious fire have been found. Blue or green staining of water has been found where there was current on

water service pipe but no current on house pipes. Non-metallic jointing compounds substantially increase resistance or impedance of electrical path along water main.—*H. E. Babbitt.*

Prevention of Water Pipe Corrosion With Cathodic Protection. STARR THAYER. Tex. W. W. Short School. **21:** 42 ('39). Corrosion is due to electrolysis, long line currents and action of soil on pipe. The last, most serious, may be reduced by the selection of materials, use of protective coating and cathodic protection. In last a counter-current is set up to keep any current from leaving pipe wall. Almost every type of corrosion can be arrested, if not completely eliminated, by some means. May not always be practical or economical to do it. Not necessary however, to assume that corrosion is just another evil connected with the business and that there is no remedy.—*O. M. Smith.*

Pipe Corrosion and How It May Be Overcome by Specifications of Materials and Linings. S. C. CLARK. Tex. W. W. Short School. **21:** 39 ('39). Only three basic materials, cement, asphalt, and coal tar, which are considered satisfactory or practical for protective coatings at present date. Much greater loss to the water works industry due to graphitic corrosion than is generally realized. That cast iron pipe does corrode from soil action is becoming generally accepted; and that this type of pipe, with adequate protective coatings both inside and outside, should be made available to those purchasers who would find it economical to install. The present specifications for coatings on cast iron pipe as set up by the A. W. W. A. do not insure getting a coating of corrosion protective value. ★[New specifications have been prepared by A. S. A. Committee A21. A. W. W. A. cooperates in this project. Specifications are now ready for final review by the committee.]★—*O. M. Smith.*

Preventing Corrosion Caused by Water. G. DEGREMONT. Rev. Univ. Min. (Fr.) **15:** 562 ('39). Author discusses causes of corrosion of metals and methods of protection. With most water supplies, protection must be obtained by formation of protective layer on metal. As determination of aggressive power of water is difficult, usual practice is to determine only ability of water to deposit protective layer; this depends on relation of contents of free carbon dioxide and calcium carbonate. Effects on aggressive power of water of various methods of treatment, including coagulation, aeration, removal of iron, softening and disinfection, is discussed. Methods of treatment of aggressive waters include aeration for removal of carbon dioxide; neutralization by addition of soda, soda ash or lime; neutralization by filtration through marble, magnesia, calcined dolomite, and certain commercial products such as "Neutralite;" and protection by addition of inhibitors. At Carnac (Fr.) found that water after neutralization attacked pipes; when carbon dioxide was added before passing water through "Neutralite," protective coating formed and corrosion ceased. In some instances, as at Rennes (Fr.), necessary to add sulfate to water to attain a certain ratio of sulfate to carbonate and prevent attack on lead. Water from impounding reservoirs or lakes often contains little mineral matter and carbon dioxide, but much organic matter.

Such substances must be oxidized, generally by chlorination, before treatment of water by coagulation and filtration. In conclusion, author points out that it is generally more economical to treat water than to use special resistant metals and alloys. Method of treatment must be decided by examination of water in each instance.—*W. P. R.*

The Aggressivity of Drinking Waters. O. L. Bihet. Rev. Univ. Min. **15**: 393 ('39). Discusses corrosion of iron by hard and soft drinking waters. Corrosion due to chem. action in which hydrogen is replaced by iron is negligible in cold. More serious corrosion is caused by electro-chem. action due to heterogeneity in metal or to differences in degree of aeration at different points. Ferrous hydroxide is first produced and this is then oxidized, by processes which vary with different conditions, to different forms of iron oxide. In hard waters corrosion is often stopped after a time by formation of protective layer, but under certain conditions layer may not be formed. If there is an excess of carbon dioxide in water containing calcium bicarbonate, calcium carbonate is not precipitated to form layer. Presence of other salts also affects bicarbonate equilibrium, e.g. when calcium chloride or calcium sulfate are present more carbon dioxide is required to keep bicarbonate in solution; sodium bicarbonate and magnesium chloride have reverse effect. Increase in content of chloride also increases solubility of calcium carbonate, and protective layers therefore do not form easily in waters rich in chloride. Langelier and Strohecker have both shown that it is possible to determine aggressivity of water from its complete chem. analysis. Experience has shown that certain amount of oxygen must be present if protective layer is to be continuous and adherent As it is not possible in practice to de-aerate water sufficiently to inhibit corrosion, it is better to adjust conditions so that protective layer is formed rapidly. By aerating water, content of carbon dioxide is reduced and that of oxygen increased. Filtration through calcite is simple but it is difficult to reach point of equilibrium. Addition of lime needs complicated apparatus and constant attention. Filtration through calcined dolomite is also used, particularly in Germany. In soft waters concentration of oxygen is of more importance than carbon dioxide in determining aggressivity. Crystalline form of iron oxide produced from ferrous hydroxide depends on form in which oxygen is present (gaseous oxygen, oxygenated water, etc.), speed at which it is supplied; *p*H value, and temp. Structure of oxide formed in pipe may therefore be very variable, even when its chem. composition is constant. Aggressive soft waters usually contain free acids, other than carbonic acid, and *p*H may be as low as 4. Though in great majority of instances no damage has been caused to pipes by water, some waters should be examined before they are used; not only may corrosion reduce life of pipes but traces of iron in water cause turbidity and stains and corrosion of lead pipes may lead to lead poisoning.—*W. P. R.*

The Effect of Water Treatment on Corrosion. U. R. Evans. Chimie & Industrie (Fr.). **41**: 492 ('39).—Corrosion by natural waters is diminished by deposition of calcium carbonate. Precipitation can only occur after "aggressive" carbon dioxide present in many waters has been neutralized. Content

of aggressive carbon dioxide may be decreased by lime-soda treatment, but is likely to be increased by base-exchange softening. Can be reduced by subsequent filtration through magnesite, cascading, etc.—*I. M.*

Tests of Corrosion Inhibitors for Water Treatment in Air-Conditioning Equipment. James H. Wilson and Edward C. Groesbeck. J. of Research, **24**: 665 (June '40). Protection of air-conditioning equipment against corrosion becoming increasingly important with expanding use. Corrosion protection necessary in industrial regions where air contains oxides of S and C. Reduction of losses from corrosion may be done by careful selection of materials of construction or by addition of suitable inhibiting chemicals to water. In tests reported on, following corrosion-inhibiting water-treatment chemicals used: sodium dichromate, sodium silicate, sodium phosphate, and sodium carbonate; conc. varied from 100 to 500 p.p.m. and pH maintained between 8.0 and 9.0 (some tests made with pH 4.0–5.0). 6 ferrous sheet metals tested: (1) copper bearing steel; (2) open-hearth iron; (3) alloyed open-hearth iron; (4) low-alloy steel; (5) wrought iron of new "synthetic" type; and (6) hand-puddled wrought iron. All of inhibitors tested, with exception of 100 p.p.m. Na_2CO_3, decreased rusting of iron and steel; inhibitors in order of efficiency (in conc. used) as follows: chromates, silicates, phosphates, carbonates. With silicates, the higher the ratio of SiO_2 to Na_2O the higher the inhibiting action. Little difference in resistance to corrosion found in metals tested. In all inhibitors used, corrosion to some extent occurred in crevices but failed to occur on flat, uniformly exposed, metal surfaces in 2 instances.—*Martin E. Flentje.*

QUALITY

Capacity of Some Types of Tap Water to Bring Lead in Solution. J. E. Carriere and L. Kooymans. Water (Neth.). **24**: 1 (Jan. 12, '40). Nearly all experiments conducted are faulty; using pieces of lead or pipes for a short time. Experience has shown that tests conducted in conformity with practice over a long time produce valuable information. Tests were conducted with new lead pipe with a vol. of at least 2 liters, wound in a spiral, having necessary taps, through which water was run by day and closed during night. In morning, water having been in contact with pipe during night (for 16 hr.) was analysed. During earlier part of expt. nearly all waters brought considerable lead into solution; with some water types, after considerable variations, lead content decreased to a low level; with other waters reduction was small and considerable variation continued. Reason for variation is found in uneven and slow formation of preventive layer such as $CaCO_3$, which may loosen through opening of taps or changes in pressure. Under these conditions quantities of lead may be more than 0.3 p.p.m. (allowed in the Netherlands), but since plumbism is result of continuous use and accumulation in organism, this can be neglected. Example of results with well water of following composition: pH, 7.9; oxygen consumed, 13; Cl, 16; HCO_3, 225; CO_2, 6; O_2, 11; and total hardness of 181 p.p.m. Amount of lead in solution after standing 16 hr.

in pipe was 2.3 p.p.m. during first wk.; decreased in third wk. to 0.6 p.p.m., fluctuated between 0.6 and 0.9 during next 15 wk., decreased gradually until after 50 wk. 0.3 p.p.m. was found; and fluctuated thereafter between slightly less than 0.2 to 0.5 p.p.m. for 17 mo. Quantities of lead dissolved were greater in summer than winter shown by ave. results over several periods: average amount of lead 1st, 2nd and 3rd yr., 0.52, 0.30 and 0.23 p.p.m. with temp. above 10°C., 0.65, 0.34 and 0.24; and with temp. below 10°C., 0.35, 0.22 and 0.19. 1st, 2nd and 3rd summers give lead contents of 0.63, 0.37 and 24; during winters, 0.30 and 0.24 p.p.m.—*Willem Rudolfs.*

Effect of Tap Water on Film Formation of Tea. J. KOOIJMANS. Water (Neth.). **24:** 65 (Apr. 19, '40). Formation of colored, unsightly films on tea, and brown deposits on walls of tea pots, is a frequent complaint. Formation of thin film on surface of tea is result of spontaneous separation of organic material from tea leaves; film formation does not depend on type of water; intensity is determined by kind of tea and acidity of tea extract. Formation of heavier film on surface and one which sticks to walls is also separation of organic material (theine, tannin), but is preceded by calcium carbonate formations. $CaCO_3$ formation is influenced by bicarbonates present in water; composition of water and type of treatment affects film formation; water with 90 p.p.m. bicarbonate hardness has slight film formation, increasing with increased hardness. Colloidal organic extracts are affected by the pH of the water so that color of tea is affected by metal and acid ions; iron in ferric form combines with the tannin producing a dark violet color. The greater the alkalinity of water the darker the color of tea.—*Willem Rudolfs.*

Experiences With the New Rubber Joint Packing. W. R. LADUE. W. W. and Sew. **87:** 60 (Feb. '40). Recent experiences with new water mains indicate that coliform organisms frequently reappear after initial sterilization of mains. Trouble seems to originate with fibrous joint-packing materials. Attempts at sterilizing these materials proved fruitless. New rubber packing material, used at Akron, Ohio, has given tight joints, low bacterial counts, easy handling, and has reduced labor and jointing-compound loss.—*H. E. Hudson, Jr.*

Improving Water Quality. L. A. MARSHALL. Ohio Conf. Water Purification, 19th Ann. Rept. p. 59 ('39). Extensive data are given regarding water quality and chemical dosages at Division Ave. Filtration Plant, Cleveland, during period '26–'39, together with typhoid death rate during past 35 yr. Increasing chlorine dosage to 8.5 lb. per mil. gal. (about double usual dosage) gave an almost sterile water as judged by agar counts, gas-formers and turbid broth tubes, provided ammonia was not applied in conjunction with chlorine. When ammonia was applied, results were not much different from those with lower dosages. Higher chlorine dosages resulted in complaints regarding taste. Persistence of residual chlorine was decidedly increased by ammonia in chlorine—ammonia ratios of 4–5:1. When this ratio was exceeded, residual chlorine disappeared more rapidly than when ammonia was not applied.—*R. E. Thompson.*

Improving Water Quality: Super-Chlorination Results on a Plant Scale at Upper Sandusky, Ohio. J. R. LOWER. Ohio Conf. Water Purification, 19th Ann. Rept. p. 69 (139). Super-chlorination is defined as application of sufficient chlorine to satisfy disinfection and oxidation demand of water. Upper Sandusky plant, treating about 300,000 gal. of Sandusky R. water per day, consists of softening unit, 5-mil. gal. res. providing 5 days' storage, and filter plant. Chloramine is employed for sterilization, Cl_2:NH_3 ratio being 3.5:1. Chlorine dosage of 0.6–6.0 p.p.m., sufficient to give ave. chlorine residual of 0.25 p.p.m. in filter effluent, is applied as water flows from carbonation basin into res. Rate of disappearance of residual chlorine as water passes through res. and filter plant is an index of the oxidation effected. Treatment eliminates tastes due to algae and gives effluent of excellent bacterial quality.—*R. E. Thompson.*

Improving Water Quality: Super-Chlorination at Norwalk. G. A. HALL. Ohio Conf. Water Purification, 19th Ann. Rept. p. 74 ('39). Water is drawn from 2 impounding reservoirs with combined capacity of 360 mil. gal. Ave. amount of water treated is 0.88 m.g.d. Chlorine dosages as high as 7.69 p.p.m. prior to filtration and 1.58 after filtration are employed for controlling tastes and odors caused by algae and decomposing vegetation, filters acting as dechlorinators. When super-chlorination was commenced, filter sand was coated with manganese. Residual chlorine did not appear in effluent for almost 2 yr. Experimentally, as much as 30 p.p.m. chlorine was applied to water on top of filters without residual appearing in effluent. High bacterial counts and gas-formers, as well as algae tastes, are reasonably well controlled by super-chlorination.—*R. E. Thompson.*

Improving Water Quality: A Discussion of Non-Confirming Gas-Formers. CLARENCE BAHLMAN. Ohio Conf. Water Purification, 19th Ann. Rept. p. 77 ('39). In judging quality of water, content of non-confirming gas-formers should be known in addition to agar count and coliform index. Significance of these non-confirming gas-formers and their prevalence at St. Martin, Williamsburg, Batavia, Blanchester and Cincinnati are discussed. At Cincinnati, post-chlorination effects ave. reduction in coliform bacteria of about 95% but does not appreciably reduce non-confirming gas-formers. Increasing the dosage of coagulant employed decreases but does not eliminate them. Complete removal of all types of bacteria should be objective of purification plant operators.—*R. E. Thompson.*

Improving Water Quality with Chlorine. A. E. GRIFFIN. Ohio Conf. Water Purification, 19th Ann. Rept. p. 80 ('39). With practically all waters, residual chlorine curve rises, flattens out and then decreases as chlorine dosage is increased. Beyond break-point, i.e., dip in curve, residual usually rises in direct proportion to increase in applied dose. During early part of residual rise, tastes and odors are prone to increase, reaching max. at first max. residual chlorine, and then drop to min. at or near break-point. Dosage at which tastes and odors disappear varies widely and must be determined for each individual water. Curves are given for 2 waters: in 1, break-point occurred

at 26 p.p.m. and in other at 0.75–1.0 p.p.m. Experience to date indicates that magnitude of dip in residual chlorine curve at break-point increases as organic matter content of water increases.—*R. E. Thompson.*

TASTE AND ODOR CONTROL

Water Treatment Problems: Taste and Odor Elimination by Super-Chlorination. J. B. Baty. Can. Engr. **78:** 19 (Feb. '40). Super-chlorination more widely adopted as means of taste and odor elimination. Success of process depends upon complete oxidation of substances causing taste and odor. Can be effected only by applying sufficient quantities of chlorine and allowing adequate contact period. Too low dosages of chlorine may intensify tastes. Oxidation is complete only when residual chlorine rises progressively as chlorine dosage is increased. Shown that in highly polluted water residual chlorine may decrease with increased chlorine dosage until point is reached where oxidation is complete. Sulfur dioxide and granular activated carbon are most commonly used de-chlorination agents. Theoretical sulfur dioxide-chlorine ratio is 0.9:1.0 and carbon-chlorine ratio 1:11.8. Sodium bisulfite and thiosulfate are effective also, but are used less extensively. Small residual chlorine content is generally allowed to remain in water, as in disinfection process. Super-chlorination has been employed to correct taste and odors due to phenols, algae, decomposing vegetation, hydrogen sulfide, iron, and sulfur bacteria. Chlorine dosage at plants for which data are available range from ave. min. of 2 to ave. max. of 4.5 p.p.m., depending on concn. of taste-producing substances. Contact period varies from ave. min. of approx. 2 to ave. max. of approx. 5 hr. Residual chlorine before de-chlorination varies from 0.35 to 2 p.p.m.—*R. E. Thompson.*

Super-Chlorination Practice. Louis J. Alexander. W. W. and Sew. **86:** 454 (Nov. '39). Super-chlorination dose is one which leaves "stable residual." Granular activated carbon seems good de-chlorinating agent if water is filtered prior to carbon filtration. Otherwise growths occur in carbon. When used with super-chlorination, granular carbon serves simply as de-chlorinator. Writer has used rates of flow of 2 g.p.m. per cu. ft. of carbon for over 2 yr. with good de-chlorinating results.—*H. E. Hudson, Jr.*

Super-Chlorination for Taste and Odor Control. J. M. Lloyd. Southwest W. W. J. **22:** 25 ('40). Data shown for 16 mo. operation at Tyler, Tex. indicate that super-chlorination of lake water may be maintained during winter periods by using as low as 2.5 p.p.m. of Cl where as much as 7.3 p.p.m. is required at other times. More Cl was required when CO_2 and the H_2S content in lake increased—*O. M. Smith.*

Break-Point Chlorination for Taste Control. William J. Orchard. Eng. News-Rec. **124:** 521 (Apr. 11, '40). Illustrated by means of curve that residual chlorine content of chlorinated water increases in decreasing proportion to amount of chlorine applied. As dosage is increased, residual chlorine curve

flattens out and when sufficient chlorine has been added to oxidize taste-producing organic substances, residual drops to min., and tastes and odors disappear. This is called the "break-point." Chlorination beyond this point progressively increases residual chlorine. This method of taste and odor removal has been found very effective, although in some instances tastes of less intensity persist. A means of automatically controlling residual chlorine has also been developed. Apparatus consists of 2 electrodes, one immersed in stream of unchlorinated water and other in stream of chlorinated water. Differential potential between electrodes is transferred to recorder and, if desired, to means of controlling chlorine application. Device is applicable to control of sub-residual chlorine dosages, such as used in sewage treatment. —*R. E. Thompson.*

Ozone for Water Treatment. J. B. KLUMPP. Eng. News-Rec. **124:** 168 (Feb. 1, '40). Lack of suitable equipment and high operating costs have retarded adoption of ozone treatment in America. More efficient apparatus is now available. Ozone is generated by passing thoroughly filtered and dried air through silent blue corona discharge created between dielectric plates at high voltage. Ozonized air, contg. approx. 0.5% ozone by vol., is applied to water under pressure and mixed with it by elec.-driven agitators. Over-all efficiency is 9–14 kw.hr. per lb. of ozone generated, depending on atmos. conditions. At Whiting, Ind., pilot plant of 3600-gal. per day capac. succeeded in producing palatable water where all present chem. methods had failed to remove medicinal tastes due to industrial wastes. A 4-m.g.d. plant is now under construction. Peak ozone demand is estd. at 15 lb. per mil. gal. and ave. at less than 10 lb. With max. energy demand of 14 kw.hr. per lb. and elec. energy at 2¢ per kw. hr., cost would be $2.80 per mil. gal. Older types of plants have been in continuous use at Long Beach and Hobart, Ind., since '30 and '32, respectively.—*R. E. Thompson.*

Ozone Goes to Work. FREDERICK H. DECHANT. Eng. News-Rec. **124:** 516 (Apr. 11, '40). In '38, water supply from Cocalico Creek was developed to supplement spring supply of Denver, Pa., a community of 2,100 people. Plant consists of intake trash rack and fine screens, coagulation and sedimentation basin, dry-feed machines for applying alum and lime, 2 mechanical gravity filters with combined capacity of 0.3 m.g.d., and chlorinator. Power is provided by diesel engine-drive generator. Disagreeable tastes and odors during '39 drought led to adoption of ozone for taste removal and sterilization. Air supply to ozone generator, which has rated capacity of 5 lb. per day, is compressed to 10 lb. per sq.in., cooled, and expanded to 5 lb. per day to remove 80% of contained moisture. Remaining moisture is removed by activated aluminum driers, which are reactivated with warm air. Dielectric plates of ozone generator are of aluminum and glass and impressed voltage may be increased to 25,000. Ozonized air, containing about 0.5% ozone, is mixed with filtered water by means of "Aloxite" diffusers and absorption wheel, through which all filtered water must pass. Ozone plant was placed in operation in March.—*R. E. Thompson.*

Construction and Operation of Activated Carbon Filters at Buckau-Magdeburg (Germany). WERNER KÜHNE AND ERWIN HELLER. Gas. u. Wasser. (Ger.) **82:** 769 (Nov. 25, '39) and **82:** 784 (Dec. 2, '39). Increased demand in water required re-use of previously abandoned filter plant using water from Elba R. to reinforce output of ground water supply. Raw water is turbid, has phenol odor and moldy taste and varies widely in mineral composition. On ave. it contains 80 p.p.m. Cl^-; 1.66 p.p.m. Fe; 0.18 p.p.m. Mn; 200 p.p.m. total hardness. Organic pollution is heavy. Oxygen consumed is 58 p.p.m. and phenols average 0.09 p.p.m., but can get as high as 0.25 p.p.m. After reconstruction of plant treatment of water consisted of sedimentation, Puech-Chabal filters, addition of coagulants (alum and bleaching clay), mixing chamber, sedimentation, rapid sand filters, followed by slow sand filters, activated carbon filters and weak chlorination (0.25 p.p.m.). ★[This succession of 4 different filtering operations shows that more importance is given to removal of impurities (incl. bacteria) than to American practice of depending on chlorination to kill the organisms.]★ Addition of 40 p.p.m. of bleaching clay was found to be efficient in removal of phenols and in helping to settle alum floc. Dosing of aluminum sulfate has to be regulated carefully and in turbid water 0.4 p.p.m. of chlorine is also added to reach isoelectric point of a pH from 6.6-6.7 for best floc formation. During winter cold water causes difficulties for formation of alum floc and secondary floc formation is then often observed over slow sand filters. Activated carbon is used to remove last traces of odor, taste and color and found to remove also last traces of iron. Use of powdered activated carbon tried on top of slow sand filters and also mixed into sand, but had very short period of activity as too much organic material was still present in water. Better results obtained by passing effluent of sand filters through filters of granular activated carbon, provided enough time of contact is allowed. Final carbon filters consist of 6 units, each 10′ in diam., containing about 7 tons of activated carbon, forming a carbon depth of 9′. 4 filters contain "Hydraffin Carbon U/III" with grains 3-4 mm., 2 other "Hydraffin Carbon U II/III" with grains 2½ to 3½ mm. in diam. Rate of filtering is of 130′ per hr. Loss of head is, after washing, 1′ 8″. When it rises after several weeks of operation to from 5′ to 7′, filter has to be washed. When carbon loses its activity has to be regenerated, whereby about 10% is lost. Iron deposits are removed with hydrochloric acid free of arsenic. High-temp. steam is then used for regeneration. Carbon filter causes reduction in dissolved oxygen and slight increase in free CO_2, which may indicate that not only adsorption takes place in it. No increase in bacteria was observed.—*Max Suter.*

Revivifying Bone Char. New Method and Apparatus. EDGAR WHITMAN RICE. Ind. Eng. Chem. **31:** 1516 (Dec. '39). Though bone char has advantage of removing considerable quantities of mineral matter from sugar soln., it is less effective decolorizer than some other carbons. It is preferred in sugar mfg. because of small weight loss on reactivation, though better methods of preparation and activation are needed. Bone char is 60% carbon, whereas decolorizing carbon is practically 100%. Partial combustion under controlled conditions with products of combustion from a carbonaceous fuel, e.g., illu-

minating gas or oil, was found to provide satisfactory activation of bone char. Scale plant constructed had capacity of 2 tons per hr. Consisted of rotating drum 4′ in diam. and 35′ long. with firebrick combustion chamber at lower end. Temp. was controlled by thermocouple in stream of outgoing treated material. Upper end enclosed in brick chamber with large flue and large duct leading to sizeable fan. A mixture of air and part of the gases delivered by this fan were used to cool reactivated char and to elevate it to settling chamber from which gases were recirculated through combustion chamber and drum. Recirculation is necessary for proper operation and permits lower activating temp. Oil was used as fuel. Time and temp. for dry char were 10 min. at 400°F.; for freshly washed damp char from mfg. process 30 min. at 700°F. With carefully controlled temp., considerable excess air could be used. Cooling effect of damp char entering drum lowers stack temp. to about 140°F., preventing excessive heat losses. Equipment can be arranged to stop automatically if any one step is interrupted, and since temp. control is not as critical as first supposed, little attention is required and labor cost is low. Cost of apparatus is low as compared with other activating methods, and space required is smaller. Decolorizing power of reactivated char was comparable to that with retort kiln and Weinrich apparatus.—*Selma Gottlieb.*

Successful Taste and Odor Control in El Dorado, Kans. A. E. French. Pub. Wks. **71:** 1:23 (Jan. '40). City takes water from 360-acre Lake El Dorado which has capac. of 1 billion gal. Intake has 3 inlets, at 11′, 21′, and 31′ depths. Water treated in 2.5 m.g.d. capac. filtration plant. In Feb. '38, 150 lb. activated carbon per mil. gal. failed to remove all of fishy taste caused by 2 mil. standard units per liter of *Synedra*. Grassy taste due to 1 mil. s. u. of *Anabaena* controlled with carbon in Aug. '38; algae then killed off with 1 lb. per mil. gal. $CuSO_4$. 500,000 s.u. *Navicula* caused no trouble in Mar. and Apr. '39. Trouble experienced with filters clogging when over 2 mil. s.u. *Melosira* present with 500,000 s.u. per liter going on to filters, helped by coagulation to decrease count to 100,000, but problem not finally solved until organism removed with $CuSO_4$ application of 1.2 lb. per mil. gal.—*Martin E. Flentje.*

METERS AND SERVICES

Metering and Accounting. Marshall S. Dutton. Am. City. **55:** 6:58 (June '40). Although accounts were accurately kept at Oak Park, Ill., no degree of control over them was exercised. As water is purchased from Chicago, on metered basis, input was well known. Input minus Oak Park pumpage showed losses which also were a matter of concern. Short account of billing and collecting scheme is given. With almost 12,000 customers, only little more than $1,100 was written off at end of '39. Losses and unaccounted-for water amounted to only 12.3% of total pumped, but routine surveys to detect leaks and to insure proper operation of valves and hydrants are made. Most leaks were found to be on services.—*Arthur P. Miller.*

A New Plan of Rewriting Meter Reading Sheets. L. A. Mayo. Edison Elec. Inst. Bull. **7:** 587 (Dec. '39). Rewriting of meter reading sheets a problem of utility accountants for years. On assumption that such sheets for

electric utilities of country are rewritten every 2 or 3 yr. and 5 postings transcribed from old to new sheets, work involved will result in 125 million postings each time sheets are rewritten. Description and illustrative diagram given of method adopted by Conn. Light and Power Co. with about 240,000 electric, gas and water meters. Steps in method involve (1) addressographing new sheets; (2) tabulating billing data from a punched card to master sheet; (3) running master sheets and new route sheets through transfer posting machine to transcribe data mechanically; (4) copying special instructions and notations to new sheet manually. Main feature of method involves use of "numeric" punched cards and tabulating equipment. Rewriting costs reduced 50% by method, and transcribing work accomplished more rapidly and accurately.—*Martin E. Flentje.*

Rewriting Meter Reading Sheets by Alphabetic Tabulating Cards. J. O. HILL. Edison Elec. Inst. Bull. **7:** 591 (Dec. '39). Narragansett Electric Co. has recently rewritten meter reading sheets by means of automatic alphabetic tabulating equipment, employing cards with punched holes which are transcribed automatically month after month with no worry as to accuracy. This equipment, by means of card on which is automatically punched all previous collected information and to which current meter reading is electrically added, will, when passed through a machine, record in bill form all data pertinent to customers consumption, amounts, name and address, and at same time provide proof of billing, summaries of sales, etc. Method as near to perfection as could be expected with regard to accuracy, also speedier and cheaper. Believed in future it may be possible to record current month's meter reading directly on advanced billing card and do away with old style meter reading sheet.—*Martin E. Flentje.*

Diagonals Form Specials for Meters. D. D. GROSS. Eng. News-Rec. **124:** 532 (Apr. 11, '40). Diagonal-flange specials, devised by J. C. Sweeney, are used in Denver, Colo., to facilitate installation and removal of 4, 6 and 8″ meters. In case of 6″ size, special consists of 2-piece flanged casting about 19″ long, with diagonal flange at 30° to vertical midway between 2 face flanges. Costs, in lots of 6, are: 4″—$13.50, 6″—$16.25, 8″—$18.00. This is less than cost of expansion joints sometimes used for same purpose.—*R. E. Thompson.*

Means to Reduce Water Wastes. KURT HIDDEMANN. Gas-u. Wasser. (Ger.) **82:** 823 (Dec. 23, '39). Means extend to two types: (1) to find leakages and repair them immediately, (2) to have water meters sensitive and registering correctly. Leakage is discovered by listening systematically with an earshell along distribution system at night. Simple earshell is used, since apparatus using amplification show too many interferring noises. Number of leakages found is nearly proportional to number of shifts active in this work. Each shift consists of 2 men, and premium is paid to each shift for each leakage found. Others receive this premium also for announcing a break in distribution system. Meters are exchanged systematically every 4 yr., but are also checked by recording meters which indicate defects in house installation. Volumetric meters of the type of ring piston meters have been found to

be more sensitive to low flows. By using all of these means, leakage was reduced from 22% in '33 to 15% in '37.—*Max Suter.*

British Standard Specification for Capillary Joints for Copper Tubes (Internal Dimensions of Sockets). British. Stand. Inst. (Specification), No. 864, ('39). Refers to that type of pipe fitting which is used in conjunction with light-gage copper tubes in accordance with B.S. 659, and in which joint is made by flow of solder by capillary action along annular space between outside of tube and inside of the socket of fitting, size of this annular space being dimensionally accurate within close limits. This specification refers to fittings of the sizes $\frac{1}{8}$"-2".—*I. M.*

ADMINISTRATION, PERSONNEL AND PUBLIC RELATIONS

The "Fifth Column" in Public Service. J. E. Bullard. Pub. Util. Fort. **26:** 3 (July 4, '40). Well known principle of Marxian doctrine that workers in transportation and communications industries are in peculiarly strategic position to wreck capitalism. First thing Nazi "fifth column" did when Norway was invaded was to make bee-line for powerhouses and telephone and radio stations, when the signal was given. In U. S., communists and their "fellow travelers" appear to have made special effort to infiltrate union organizations of utility workers. Last May reported that federal agents in Los Angeles investigated 3 attempts in 10 days to interfere with water and power supplies of aircraft mfg. plants. Utility workers will be called upon to show a greater degree of unswerving loyalty than workers in other lines. Citizenship status is one of obvious points of inquiry by management into utility personnel. Stated many times by those in authority, government employees cannot strike. It is certain America cannot afford a strike in utility industry during rearmament program. Apparent to world that we favor one European warring faction and not other. Side not favored is expected to impede our help to favored side, financed from abroad—axiomatic. During last world war, suspected utility employee could be discharged and management did not have to give reason. Today picture is changed. Way must be found for government to eliminate saboteurs from utility business. Any employer with payroll of any size knows from past experience, difficulty of reasoning with govt. where labor is involved. Advantageous to any nation interested in impeding production here to have active agents connected with administration of labor laws. Continuation of uninterrupted utility service too essential to permit even possibility of utility workers being called out on sympathetic strike for benefit of stagehands, beauty operators, or alleged harassed refugees of erstwhile Spanish Republic. Utility management and labor will cooperate when they know each other personally and realize responsibility developed by brilliant tradition of public service of utility business.—*Samuel A. Evans.*

The Futility of Managed Economics. Leonard P. Ayres. Pub. Util. Fort. **25:** 88 (Jan. 18, '40). In progress toward recovery U. S. ranks 21st among 22 nations, while France is 22nd. In depression, both nations had in common two similarities, both followed programs of managed economics,

govt. left unchanged business capitalistic structure, interposed progressive regulation, incurred deficits to subsidize and finance relief, great reductions of private capital in business. Key to central problem of depression, both countries imposed continuously changing regulations, restrictions, interventions and state competitions. As these multiplied private money held back, investors will take risks on probability of future gains; when risks increase and prospects of future gains reduced, investing ceases, riskless bonds bought or money lays idle in banks.—*Samuel A. Evans.*

The Congressional Economy Line Forms to the Right. HAROLD BRAYMAN. Pub. Util. Fort. **24:** 89 (Jan. 18, '40). Survey indicates utilities have little to fear from congressional legislation. Pres. Roosevelt started off on economy, expenditures reduced, adding to appropriations puts burdens on Congress. Keen observers expect little new legislation in any field; history of pre-election congresses, debate, purpose, maze of politics, do nothing. The gigantic grid power system has no chance of congressional approval unless as a national defense proposition. Private statements of Army general staff, show doubt as to invulnerability of grid system, however there are certain features which appeal to the military. By generally anticipated circumstances the SEC seems destined to make '40 very critical for great public utility holding companies under the '35 Utility Act. Corcoran and Cohen credited plan to coordinate 20 federal agencies; would bring into Interior Dept. such projects as, Bonneville, Fort Peek, TVA, REA and others. There is, however, the D. E. Lilienthal opposition. All boils down to—when considering relative advantages of public and private ownership, and potential savings to consumers by cheaper power, cognizance must be taken of fact that Govt. "yardstick" rates must include or allow for lost tax revenues.—*Samuel A. Evans.*

A Yardstick of Residential Lot Needs. HELEN C. MONCHOW. J. Land & Pub. Util. Econ. **15:** 474 (Nov. '39). Chicago Regional Planning Assn., from data since 1871, developed rule-of-thumb measures of land-use in terms of pop. Approx. 50′ business frontage for 100 people, 10 acres of recreational land for 10,000 persons, 4 acres industrial land for each 1000 persons. Could a corresponding ratio be developed for residential land use? No information recorded on residential lots; measure of need had to be substituted for a measure of use. No. of families was calculated from available records, corrected for multi-family influence and number of residential lots determined, assuming one dwelling per lot. From 16 independent cities in vicinity of Chicago and 19 suburban areas, rule-of-thumb measure is 22 residential lots per 100 of population.—*Samuel A. Evans.*

Service to Water Works Men. NORMAN J. HOWARD. Eng. Cont. Rec. **53:** 13:31 (Mar. 27, '40). Activities of A.W.W.A. since founded in 1881, during which period it has increased to continent-wide membership of nearly 4,000, are reviewed. Notable achievements in water supply during that period include remarkable reduction in typhoid mortality and the development of

slow and rapid filtration, chlorination, taste and odor control, etc. Members of A.W.W.A. prominently associated with researches which led to all these outstanding accomplishments. In addition, A.W.W.A. has prepared and published water works manuals and specifications for materials and has inaugurated or co-operated in a host of activities which are of vital importance to water works profession and community at large.—*R. E. Thompson.*

A Model of a Modern Water Filtration Plant as a Project in High School Chemistry. WILLIAM MAYROSE. J. Chem. Ed. **16:** 83 (Feb. '39). Chem. students at the Muskegon, Mich. Senior High School constructed a wooden display model of the city water filtration plant, using as guide the blueprints used in constructing actual plant. Scale was $\frac{1}{4}''$ to 1′. Water pipes were represented by $\frac{1}{8}''$ diam. iron pipe, each line painted a different color. Part of model was shown in section, glass-covered, to facilitate examination. Model was labeled at appropriate places with actual size of real structure and function of that part. All parts of plant were shown, including dry feed machines for alum, lime and activated carbon, office, laboratory, chlorinator, chemical storage, mixing chambers, coagulation basins, filters, operating tables, pipe gallery, etc. Similar model of city's new sewage treatment plant is being built, and two models will be used as a unit for study of water supply and sewage treatment of a city.—*Selma Gottlieb.*

To Assure the Consumption of Water. VICTOR GERMAIN. L'Eau. (Fr.) **32:** 75 (Jul. '39). Attempts can be made to increase consumption of water by (1) promoting sewage disposal, including education as to needs, means and costs (2) expressing water rates and construction costs in terms understandable to the layman (3) pointing out losses due to insufficient irrigation of growing crops, and time lost by housewives in carrying water. Other arguments will occur to the imagination and propaganda will follow for using them. Motto should be: "To have one subscriber is good, to have two is better." One should not give up until all are provided with every comfort practically realizable.—*Selma Gottlieb.*

To Increase the Consumption of Water. VICTOR GERMAIN. L'Eau. (Fr.) **32:** 65 (Jun. '39). Where resources are abundant, price of water can be adjusted to favor larger consumption. Increased water sales will pay increased dividends on capital invested. Municipalities can urge population to take more advantage of water for which they are paying. Concessionaires can advertise advantages of daily baths, cultivation of flowers and other irrigation, sanitary water supply for cattle, etc. Cooperation of manufacturers of equipment should be solicited. Articles carefully prepared and soberly illustrated in the local press will have wide influence.—*Selma Gottlieb.*

Water Conservation Program on a Vast Scale. ANON. Am. City, **55:** 4:55 (Apr. '40). All available avenues of publicity were enlisted in recent N. Y. City campaign for water conservation. Metropolitan dailies including foreign-language newspapers, school newspapers, radio, news reels depicted the depleted condition of res. and illustrated ways in which water might be

saved. Posters were placed in all transit systems, hotels, restaurants, banks, markets and in all possible places apt to be frequented by large groups. Billboards, pamphlets were distributed to schools, clubs, etc., throughout the city. Hospitals and other associations included notices in their regular bulletins; discussions and essay contests on water shortage were conducted in schools, even the cartoonist Rube Goldberg subscribed to the campaign with his cartoons which appeared in one of the leading dailies. The Department of Water Supply augmented its regular inspection program of the City's 5,000 miles of water mains and 640,000 service pipes by a force, recruited from NYA, which, under the supervision of the Department's regular inspectors, made a house-to-house survey searching for leaks in plumbing fixtures. City contributed by discontinuing use of hand hoses for flushing streets and instead conscripted use of Fire Department equipment drawing supply from Hudson R. for this purpose. Perhaps dramatic announcement that City could count on a supply sufficient for only four months had great deal to do with arousing people to cooperate. At any rate fact that good results can be accomplished by large-scale organized effort is statistically supported by figures showing that average daily consumption which had reached a high of 1,005.9 m.g.d. in Aug. '38. had dropped to 839.6 m.g.d. in Feb. '40. Believed too that campaign has made consumer water conscious for all time and that water-saving habit will not have disappeared with immediate emergency.—*Arthur P. Miller.*

When Public Officials Are Exempt from Payment of Income Tax. LEO T. PARKER. W. Wks. Eng. **93:** 169 (Feb. 14, '40). Recent decisions in several higher courts, including U. S. Supreme Court, have laid down new law on income taxes of public officials. Decisions have reversed old law and decisions of 120 yr. standing. Federal employee's salary held not immune from state income tax laws (*Graves* v. *People of State of New York;* 59 S. Ct. 595) and employees of State of N. Y. held not immune from federal income tax (*Gerhardt;* 58 S. Ct. 972). Congress, with authority to lay taxes in order "to pay the debts and provide for the common defense and general welfare of the U. S." can reach every person and every dollar in the land with due regard as to the method of laying taxes.—*Martin E. Flentje.*

Certification of Operating Personnel of Water and Sewage Treatment Works. R. H. MARKWITH. Annual Report of Div. of San. Eng., Ohio Dept. of Health, 1939. p. 9. Certification of operating personnel of water and sewage treatment works was extended during '39 by means of examinations given simultaneously in 5 cities throughout state. 136 water treatment and 136 sewage treatment certificates were issued, making present total of certificate holders 486 water treatment operators and 320 sewage treatment operators. Of certificates issued since '37, 369, or 73%, of water treatment, and 199, or 59%, of sewage treatment ones were issued under "grandfather clause," in effect previous to '39. Appendix gives breakdown of grades of certificates held—in water treatment, approx. 10% are Grade A; 12%, B; 40%, C; and 38%, D; and in sewage treatment, 10%, A; 12%, B; 30%, C; and 48%, D.—*Ed.*

The Rights of an Inventor-Employee. H. H. Snelling. Mech. Engr. **62:** 7 (July '40). Object of paper is to indicate respective rights of employer and employee with regard to inventions made during usual course of employment. Large corporations invariably require new research employees to sign printed contract setting forth exact conditions under which employee must assign patent rights. But many small organizations make no such provision, in which case employee has legal right to obtain patent for work done in regular course of employment and sell it to business rival of employer. Exception is when employee is hired to invent particular thing for which he obtained patent. Throughout all decisions on question of employee's share in his own invention, there is surprising lack of appreciation by courts of value to employer of right of exclusion. So frequently, in legal opinions, employer should be satisfied with shop right, for that is sufficient to enable him to keep up with growing art. Forgotten that employer is striving for something others can be prohibited from using; something he may feature in his advertising. Not enough that his goods be excellent; they must have sales appeal. Factory cost of article is usually limited to ⅓ retail price. Equal amount goes to selling, where a key word to success is "exclusive,"—a word foreign to shop right and existing only in ownership of a patent. Perfectly possible to combine right of exclusion by employer with right to suitable recompense for employee. May best be done by parties at time when relations are friendly and interests mutual. Should provide in writing for such division of rewards of inventions, yet unborn, as may then seem fairest to both. Agreement, signed in duplicate, should be full and complete, preferably in simple language.—*Homer Rupard.*

Photographic Duplication of Records. *Editorial.* Teknisk Tidskrift, Uppl. A, (Sweden). **70:** 100 (Mar. '40). Process is described in which cost of film, of filming, and of prints, had been brought down to a new minimum, while results leave nothing to be desired. No record is exempt from risks of destruction, of which fire hazard is perhaps the chief. Loss in such case is irreparable unless there exists a copy. When copy exists and is stored at a different location from original, risk that both should be destroyed at one time is small. Moreover, it is very often desirable to use a copy for reference purposes in order to protect original from effects of repeated and incautious handling. Process described and illustrated reproduces with utmost accuracy any kind of document or drawing. It is on small-film principle, using standard 35-mm. film, size of each negative being 24 x 36 mm., from which prints are taken in any size desired. Either film or print, or both, can be stored for reference. Ordinary documents, written or printed, tend to deteriorate on storage. Light, especially sunlight, heat, and humidity are detrimental. Pure linen paper is now seldom used and whereas pure sulfite or sulfate paper ranks as high-grade, an admixture of ordinary pulp will render it liable, under action of light and air, to become brittle and discolored. Neither is ink, writing or printing, always without effect. Usual practice heretofore has been to prepare hand-written copies of documents of great intrinsic value, or of those in danger of excessive wear; chiefly because photographic reproduction

was costly and inconvenient; but process here described is quickest, cheapest, and most exact for reproduction purposes. For drawings, it has the following advantages: (1) originals do not need to be on transparent paper; (2) reproduction can be made on any scale desired; and (3) it is rapid, cheap, and strictly accurate. An incidental advantage is that, once they have been photographed, many old drawings may be discarded and much valuable storage space thereby recovered. From film negatives, prints can be taken of one, or of a few uniform sizes, as may be desired. Often desirable, also, to have simple means of reducing large and cumbersome working drawings to more convenient scale for field use. For business purposes, often desirable to have exact copies of such instruments as mortgages, contracts, scrip, agreements, insurance policies, liens of various kinds, etc., as a protection against possible loss of originals. Similarly, for card indexes, card ledgers, etc. Illustration is given of 50 small film boxes containing a complete copy of a file of 50,000 large (12″ x 10″) cards. Space required is trifling, and weight but 17 kilograms. Complete outfit costs about $350; the camera alone, about $60. Film costs about 0.7¢ per exposure; under favorable conditions, up to 300 exposures an hour are possible.—*Frank Hannan.*

The Annual Report of the Water Department of a Large City HENRY M. ROBINSON. Tex. W. W. Short School **21:** 47 ('39). If only annual reports are made, losses might continue for several months before being discovered, whereas monthly reports made cumulative will bring to light immediately any leaks, inefficiencies, etc. A monthly annual comparative operating and financial report will provide: (1) uniform method of collecting and assembling data; (2) ready comparisons; (3) all essential operating and financial data in two folders each month; (4) data on a definite schedule each month, (5) they may be augmented with any additional detail; (6) if made up on standard letter size forms are easily filed; and (7) duplicate copies may easily be made.—*O. M. Smith.*

Relative Value of Utility Systems. C. F. LAMBERT. Eng. News-Rec. **124:** 882 (Jun. 20, '40). Data regarding values of 5 utilities are extended to Jan. 1, '40. Additional plants have been added until about twice as many are now used as were originally. Values for water works are based upon 68 items in 25 systems. Relative yearly values compared with '13 and '26 values are shown in tabular form, and former are also shown graphically. Monthly values during '39, on '13 base, are also tabulated. Taking '13 value as 100, value of water works in '39 was 189.8, 2.8 lower than in '38 and 5.7 lower than in '37. Value increased from 188.6 in Jan. to 194.5 in Dec. Taking '26 value as 100, '39 value was 100.8—*R. E. Thompson.*

Legal Possibilities and Limitations of Milk Distribution as a Public Utility. W. P. MORTENSON. J. Land & Pub. Util. Econ. **15:** 438 (Nov. '39). Prior to '30 processing and distribution of milk a competitive business entirely free of public economic control. Large profits and high salaries in the '20's created public concern, by the middle or late '30's public interest turned to "labor problem" and waste in distribution. Bill presented to Wis. Legislature in

'35 permitting cities exclusive right to process and distribute milk, lost by a narrow margin. Modern economic activity varies between two extreme categories, one end public service group, other privately operated business units. Between, activities operated by private business, but subject to complete public regulation, is public utility, division between vague. Three definitions: average citizen, utility that serves him; lawyer, any business so legislated; economist, character of business and mode of operation. Recent U. S. Supreme Court decisions have emphasized all businesses are "clothed with a public interest." As society has grown more complex certain services upon which public has become dependent have been regulated for common benefit. State legislatures specify enterprises which are public utilities. Sup. Ct. decisions and rulings of commissions in regulation of milk industry in recent years show trend of regulation. Where public health and welfare is involved tendency has been to stricter regulation. Courts tend to sustain regulation in enterprises formerly regarded as purely private. Sup. Ct. stated regulation touching prices is not dependent upon business being classed as private or a public utility. Justice Cardozo delivering opinions of Sup. Ct. states: "One state cannot place itself in a position of economic isolation in dealing with another state, neither the power to tax or police power can be used as an economic barrier against competition with the labor or products of another state." N. Y. milk control law provided dealers in market before a certain date could sell unadvertised milk cheaper than advertised brands, dealers enter after aforesaid date denied price differential. Sup. Ct. held latter discrimination to be arbitrary, unreasonable, and violating equal protection clause of Fourteenth Amendment. On fundamental question of power of Federal Govt. to fix minimum producer prices for milk in interstate commerce Sup. Ct. ruled: "Where commodities are bought for use beyond state lines the sale is part of interstate commerce. The authority of the Federal Govt. over interstate commerce does not differ from that of the states over interstate commerce." In state power over prices Ct. stated: "The state may regulate a business in any of its aspects including prices."—*Samuel A. Evans.*

Time Limit for Filing Pollution Suits. Leo T. Parker. Munic. San. **11:** 247 (May '40). Ordinarily, owner of private property may recover damages from a municipality for pollution of his water supply, depending, however, on duration of offense, details of testimony, and provisions of statute of limitations. Latter may vary from 6 mo. to 15 yr. according to given state. Another important point of law is that right to recover damages depends upon whether acts of pollution are a nuisance *per se*, or a legal nuisance, i.e., one known to effect damages and, therefore, prohibitable. In turn, nuisance must be determined as permanent or temporary, e.g., an established sewer is considered a permanent nuisance, if any. Courts in some states, however, hold damage from sewer under certain conditions may be temporary and abatable by discontinuance or use of modern devices for sewage disposal. Other factors to be considered are, partial or total destruction of property, negligence of officials, and system changes.—*Ralph E. Noble.*

ACCOUNTING

So Depreciation Is a Technical Problem. C. E. KOHLHAPP. Edison Elec. Inst. Bul. **8:** 288 (June '40). Utilities regard depreciation as complex and technical. Probably technical but also of major importance. Unless present situations and trends are appreciated, and defensive measures adopted, industry is in danger of losing two billion dollars. This is approximately difference between existing depreciation reserves and amount retroactive straight-line depreciation would produce. Since '22, retirement accounting provided for, and not any exact mathematical or age-life process. New classification of accounts by Federal Power Commission effective Jan. 1, '37, since adopted by many state commissions. Many commissions favor straight-line depreciation, contemplating life of an "age-life" process, providing for individual property units by equal annual installments. Utility committees have conferred with depreciation committee of N.A.R.U.C. with following summary of results: (1) broader understanding of complexities of problem, (2) gradual transition from retirement to depreciation accounting, (3) additional factual data required, (4) fair treatment by commission of utilities using retirement method in good faith with rate payers, and (5) amortized cost or costless depreciation reserve is element to be considered in determining fair value for rates. Depreciation committee, in '38, recommended straight-line depreciation. '39 report indicates further investigation before final recommendation. Courts tend more and more to support commissions on technical questions. What is result if in judicially approved "value" determination, amount of depreciation deducted is twice amount of depreciation reserve shown on company's books? Commissions now say if provisions *for retirement under regulations heretofore in effect* were less than *present estimate of what depreciation was* (computed by commissions), deficiency should now be made up by stockholders. Necessity for fair play and cooperation between commissions and utilities in transition from retirement to depreciation accounting. Depreciation accounting is simply amortization or prorating; straight-line or any other process can never measure true depreciation in value sense. Consensus of independent and commission engineers that depreciation *does not* proceed in straight line; in the past courts have uniformly rejected straight-line theoretical calculations. Companies with low reserves must increase them as rapidly as possible. Fundamental principle is moral responsibility of authorities and companies to collect depreciation costs out of rates—no more, no less.—*Samuel A. Evans.*

An Asymptotic Method of Determining Annual and Accrued Depreciation. JOSEPH JEMING. Edison Elec. Inst. Bull. **8:** 27 (Jan. '40). Depreciation subject of major importance, close regulation of utilities makes proper treatment of depreciation necessary. Straight line theory, depending upon estimates of probable service life, being widely used. Workable method of calculating depreciation essential; data must be readily available, calculating methods not involved, assumptions should be valid, results should be comparable with results from other methods and sound in light of experience. In a homogeneous group of units, where number is constant ratio of retirements

to total number, should approach some constant level. Equations given for determining retirement ratio; illustrative charts and tables given. Asymptotic method makes determination of "built-up" reserve possible; impossible on basis of actuarial studies. Results must be checked by experience of those knowing the actual physical property and adjusted as required. Reasonable, as shown by applying asymptotic method to human mortality data for decade of '19-28 in U. S. Result checks perfectly.—*Samuel A. Evans.*

Disposition of Amounts in "Acquisition Adjustments" and "Plant Adjustments" Accounts. C. F. MacRae. Edison Elec. Inst. Bull. **8:** 24 (Jan. '40). Compliance with original cost provisions of new accounting classifications now virtually complete, difference between original cost and actual cost of utility plant is provisionally classified as an asset subject to court or commission review. Earlier in original cost theory, there was confusion of "disposition" with "dispossession." Assets of continuing value included in adjustment account, depreciable plant assets amortized through charges to operating expenses. Supreme Court decision in Telephone Accounting Case, '36, made effective all new classifications. Only one adjustment account necessary, generally regulatory commission approval required for disposition of amounts in this account, and no time limit for presentation to commission. Supreme Court decided accounting classification should be informative on business methods of utilities, aiding regulatory bodies to regulate utilities on matters within their jurisdiction. Court said commission has power to prescribe uniform accounting methods, but cannot compel writing off the books of a loss not sustained or giving up part of constitutional rights. Certain advantages in having entire adjustment account reviewed; under a piecemeal procedure advantage of a better showing at first and making valuable precedent mainly a tactical question.—*Samuel A. Evans.*

The Desirability of Inventory Verification by Independent Engineers. Eric G. Adams. Eng. J. (Canada) **23:** 215 (May '40). Growth in amount of information in published annual corporation reports for purpose of creating favorable public opinion can be extended through use of certificate from cons. engr. verifying and certifying inventories. Public accountant conducting annual audit has neither time nor opportunity to do more than test clerical accuracy of inventory pricing and review book records. Inventory in certain industries important element of balance sheet: to about 50% in liquor industry and 75-90% of current assets in such industries as canning, meat packing, lumber and paper. Engr's. appraisal of inventory of benefit to investors, bankers and public; independent inspection of condition and grade of goods is given, removes last major item of indefiniteness from current assets and working capital. Work complementary to that of public accountants.—*Martin E. Flentje.*

The Integration of Income and Surplus Statements. A. C. Littleton. J. Accountancy **69:** 30 (Jan. '40). Change has been taking place in form and content of income statement, income and surplus being combined in single report. General surplus was becoming mixed, no longer identified with un-

divided realized profits. Present well defined practice of separately stating appraisal surplus, paid-in surplus and earned surplus. Accountant's Institute defines earned surplus as source of current cash dividends, differing from liquidating and stock dividends. Newer corporation statutes imply, as a source, either earned surplus or paid-in surplus. Inappropriate for accounting procedure details to be enacted into statutes, accountants should exercise leadership upon this. Surplus statement may be unsatisfactory if it contains too many diverse elements. Some changes to capital surplus doubtful as charges or credits which should be made to current income or earned surplus. Integration of income and earned surplus in one statement a progressive step. Usually balance sheet informs regarding relation of various equities, relation of equities to assets, income statement gives corporation's earning power and efforts of management to employ capital in an effective manner. Management and investors interested in income statement; management requires data as an index to efficiency, investors need classification as basis for judging immediate dividend possibilities and earning power as an element in estimating enterprise value. Itemized lists give debits to revaluation surplus and debits to paid in surplus. Also a summary of items of "Idle facilities expense." Tabulated sample of simplest arrangement of practice of relating income and earned surplus. Content and organization of major statement accompanying balance sheet should constitute an informative analysis of managerial efforts to employ capital effectively. Earned-surplus-and-income statement combined so that "management efforts" reported in one statement for investors. General purpose of financial statements to transmit important factual information from management of an enterprise to absentee interests.—*Samuel A. Evans.*

Financial Statements for Investors. WILLIAM W. WERNTZ. J. Accountancy **69**: 22 (Jan. '40). SEC scrutinizes methods and techniques employed in auditing. Apparent defalcation of $458,000 was discovered in Loan Society after a registration statement became effective under '33 Securities Act. At a stop-order hearing it was found auditors did not visit any branch office of registrant between registrant's inception in '27 and '37, no notes or applications for loans verified, no loans verified by direct confirmation with borrowers. Commission held omission of examination so disregarded auditing practice as to invalidate accountant's original audit certificate. Hosiery mills case, registrant filed financial statements overstating earnings and assets about $900,000. Falsification work of employee of certifying accountants, question is whether firm exercised due care in employing accountant and reviewing his work. Commission indicated an adequate review would have exposed irregularities. Irregularities in McKesson & Robbins case first intimated when appointment of receiver for company sought. Company's inventories and accounts receivable overstated some $20,000,000. False and misleading information set forth in financial statements, certified by public accounting firm. Commission ordered public hearings to determine: (1) character, detail, and scope of audit procedure of accountants; (2) extent to which generally accepted standards of audit procedure were adhered to;

(3) adequacy of safeguards in auditing to assure reliability and accuracy of financial statements. Commission examined over 200 persons, transcript of testimony published Sep. 15, '39. Accountants as a body aware of responsibilities. If accounting principles followed is something else. Promotional enterprises generally speculative, hazards of undertaking obscured in orthodox balance sheet; valuation arbitrary, or based on appraisals or engineering reports of doubtful validity. Perhaps under certain circumstances balance sheets should not be submitted to investors. Conservatism of accountants commendable, however may be carried to extremes, often taking form in today's balance sheets, with resulting unconservatism in future income statements. Investor selling securities on understated balance sheets, misled as much as one who buys on overstated balance sheets. In *quasi* reorganizations, frequently certain disclosures are necessary for investor, when course is legal, but not in accord with sound accounting. Capital surplus should not be used to relieve income account of charges which would otherwise require to be made against "income."—*Samuel A. Evans.*

Balance Sheet Accounts and the Public Interest. M. J. Miley. Edison Elec. Inst. Bull. **7:** 598 (Dec. '39). Example and exhibit given of modern utility balance sheet showing trend to explanation by means of footnotes, or other notes, of various asset and liability terms. Marks passage of such veiled and uninformative titles as Deferred Debits, Concessions, Good Will, etc.—*Martin E. Flentje.*